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SIMULATION OF BULK MINING AT DEPTH
WITH BACKFILL IN ONTARIO MINES
Final Report - Volume 3
FIELD MONITORING PROGRAM

by

Mines Research Department
INCO Limited

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ABSTRACT

This is the final report for of the field monitoring portion of the Ontario Division of Inco Ltd. project entitled, "SIMULATION OF BULK MINING AT DEPTH WITH BACKFILL" which was partially funded under the Department of Supplies and Services contract file number 14Q.23440-6-9033. The objective of the project is to create a three dimensional elasto-plastic numerical modelling program for use by the Canadian mining industry. The original project duration was four years which has been extended by six months to allow the orderly completion of the numerical code calibration with the field monitoring data.

The following report outlines the field monitoring portion of the contract, the function of which was to collect field data that was used to calibrate the numerical code. A description of the instrumentation used and the data collection in the monitoring program over the last four years of mining in the monitoring site is given. This is followed by an analysis of the data which gives a detailed description of the rock mass response to the progressive mining at depth in this location in Creighton Mine.

SOMMAIRE

Ce rapport porte sur les mesures de pressions de terrain dans le cadre du projet intitulé "Simulation du minage en vrac de gisements à grande profondeur avec utilisation de remblai." Le projet, réalisé à la division Ontarienne d'Inco Ltée, a été payé en partie par le département des services et des équipements (numéro de contrat 14Q.23440-6-9033). L'objectif de ce projet est de créer un programme de modélisation numérique élasto-plastique tri-dimensionnel qui soit utilisable par l'industrie minière Canadienne. La durée du projet, initialement de quatre ans, a été prolongée de 6 mois pour permettre l'achèvement de la calibration numérique du logiciel avec les mesures de pressions prises sur le terrain.

Ce document traite des méthodes utilisées pour mesurer les contraintes sur le terrain. Les mesures recueillies ont servi à calibrer le programme informatique. Ce rapport décrit également les équipements de mesure utilisés ainsi que les données recueillies sur le terrain sur une période de quatre ans, pendant laquelle le site était en production. Suit ensuite une analyse des contraintes qui décrit en détail le comportement de la masse rocheuse en réponse à l'exploitation progressive du gisement en profondeur, à la mine Creighton.

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PREFACE

This project entitled "Simulation of Bulk Mining at Depth in Ontario Mines with Backfill" consists of two major components: the development of a numerical model, and field calibration of the model. The four year project started in October, 1986 and was scheduled for completion in 1990 but was extended for six months to allow the completion of the work. This is the Volume 4 final report on the field monitoring portion of the project.

This work was initiated and conducted by Inco Limited. Partial funding was provided by the Canadian and Ontario governments through the Mineral Development Agreement (MDA) under DSS contract file number 14SQ.23440-6-9033. The project is administered by CANMET and their assistance is greatly appreciated.

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1.0 INTRODUCTION

This is the final report for the field monitoring portion of the project entitled "Simulation of Bulk Mining at Depth With Backfill in Ontario Mines". The aim of the project, which was jointly funded by Inco Limited and the Canadian and Ontario governments under the Mineral Development Agreement (MDA), was to create a three-dimensional, elasto-plastic boundary element numerical modelling program that can be used by the Canadian mining industry to simulate mining at depth. There are two components to the four year project; the first being the writing of the numerical code and the second, the collection of field monitoring data (See Volume 2: "Mathematical Formulation and Code Development").

The purpose of the field monitoring portion of the project was to collect field data from two underground sites as they were progressively mined over the four and one-half year duration of the MDA contract. The mining of one of the underground sites (4500 VRM block) was modelled using the above numerical code and the simulated rock mass changes compared to those measured in the in situ monitoring program. This comparison was used in the calibration of the numerical code. (See Volume 4: "Numerical Model Calibration Studies").

This report deals exclusively with the field monitoring portion of the project. The actual field measurements collected over the four and a half year duration of the project are supplied in a Lotus 2.2 format on computer disk in Appendix A of this report which consists of a set of 3-ring binders separate from this volume. The work conducted in the calibration of the numerical code with the field data is covered in Volume 4 of these reports.

2.0 CREIGHTON MINE MONITORING SITE

The field monitoring program was conducted at Inco Limited's Creighton Mine (Figure 2-1) situated in the south-west end of the Sudbury Basin in Northern Ontario. The two monitoring sites initially chosen for the monitoring program are located in the 400 orebody between 6600 and 6800 level and 7000 and 7200 level of the mine as shown in Figure 2-2. The copper-nickel sulphide orebody at this depth (2035 to 2215 meters below surface) strikes east-west dipping 70 deg. to the north and is approximately 200 meters long by 100 meters wide. The ore host rock, which makes up the hangingwall, is norite while the footwall consists of a mixture of granite and gabbro.

2.1 Mining Method

The majority of ore removed from Creighton Mine is presently being mined using a bulk vertical retreat method (VRM). This mining method requires a top and bottom sill to be developed in the orebody above and below the mining area. The area is divided into VRM panels, each of which is drilled off using 165 mm diameter holes with approximately 3 meter burdens. In a given panel the ore is then broken by lowering explosives down the holes and progressively crater blasting from the bottom sill up in one and a half to three meter lifts until a 10 to 13 meter crown remains. All the holes in the crown are then loaded with explosives and it is removed in a single blast.

Ore is removed from the VRM panel by scooptram on the bottom sill after each blast to create room for the following day's production. Once blasting is completed, all the ore is removed from the panel and dumped into a chute for transport to the shaft and surface. The panel is then backfilled with cemented hydraulic fill prior to the mining of the adjacent panel.

The VRM panels are normally mined 13 by 13 meters square by anywhere from 25 to 76 meters high. The mining block is excavated panel by panel until all the ore is totally removed using this primary mining method.

2.2 Monitoring Site Geometry

The main portion of the field monitoring was concentrated in 4500 VRM mining block between 6600 level and 23 meters above 6800 level (which will be referred to in this report as 6700 level). The level plans at these horizons are shown in Figure 2-3 and 2-4. This block of ore was mined for six cuts above 6800 level using a mechanized cut and fill (MCF) mining method. It was then converted to VRM mining which is presently being used to remove the remaining block of ore, (83 m. x 83 m. x 53 m. high).

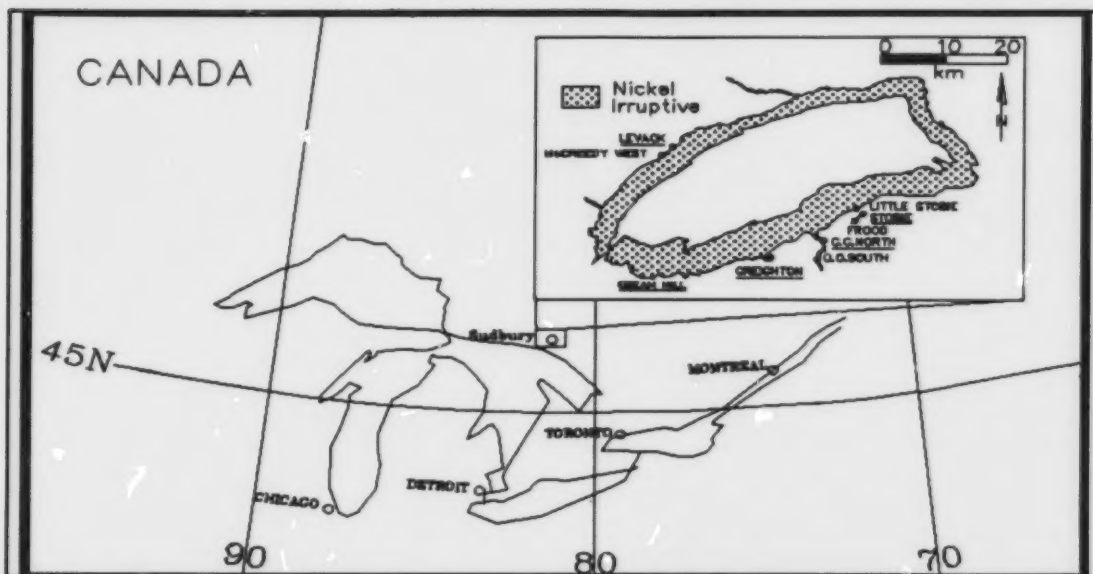


Figure 2-1 The Sudbury Basin - Creighton Mine

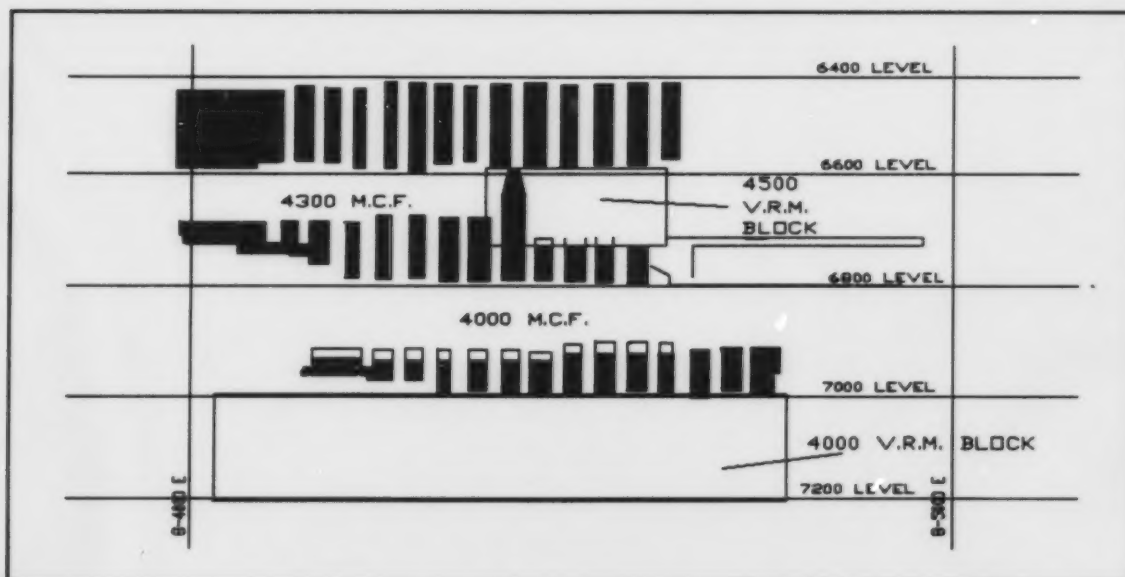


Figure 2-2 A Longitudinal Section of Lower Creighton Mine

As part of the conversion of 4500 block to this bulk mining method, a 7 meter wide by 83 meter long by 53 meter high destress slot was mined on the west side of the block as shown in Figures 2-2, 2-3, and 2-4. The slot was mined by VRM mining and removed in five separate panels in the sequence numbered in Figures 2-3 and 2-4. Rock bursts occurred in the slot during the mining of the third and fifth panel.

The creation of this destress slot, which separates 4500 VRM block from 4300 MCF block, was necessary to reduce the high horizontal stresses (96 MPa) that exist at this depth along the strike of the orebody. This would allow the V.R.M mining to progress in 4500 block within the shadow of the stress relaxation zone created by the slot. This, thereby, decreased the potential of having to drill in highly stressed ground and allowed the progressive mining to passively transfer the high stress zone to the abutments on the mining area.

The mining blocks above 4500 VRM block have been completely mined out up to 6000 level using the MCF method. Only the rib pillars remain which will not be recovered until well after the end of the monitoring program. The ore between 7000 and 6800 levels was initially mined using the MCF method. This mining area was later converted over to the vertical retreat method mid way through the monitoring program. The detailed timing of this conversion is outlined later in this report. Approximately 40 meters of ore separate 6800 level from the mining below while the destress slot was being mined.

To the west of 4500 VRM block is 4300 MCF, which was also converted over to VRM mining part way through the monitoring program. Approximately 27 meters of ore separate the 4300 from the level above while the destress slot was excavated.

The geometry of the mining areas above 6600 level is given in the input files for the 3-D elastic models at various mining stages in the appendix of Volume 4: "Numerical Model Calibration Studies". The changes in the geometry below 6600 level with the progression of the mining during the monitoring period is also given in these files and later in this report.

The second mining site initially chosen for the monitoring program was 4000 VRM mining block between 7000 and 7200 levels. The 4000 block of ore was in a virgin mining zone and under development during the first two years of the monitoring program. The flurry of activity associated with the development mining resulted in much of the instrumentation that was installed in the block during year one of the program being destroyed or damaged by mobile equipment, air concussions from blasting and general disregard for the equipment by operations. A second attempt at instrumenting the block met with similar results which lead to the area being abandoned as a monitoring site.

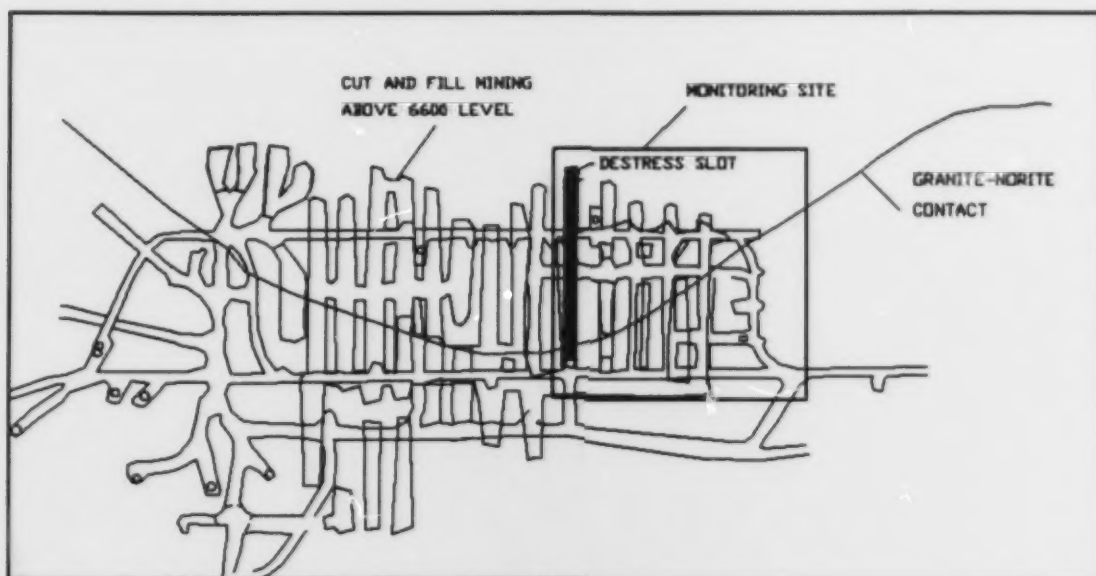


Figure 2-3 6600 Level Plan Showing The Monitoring Site

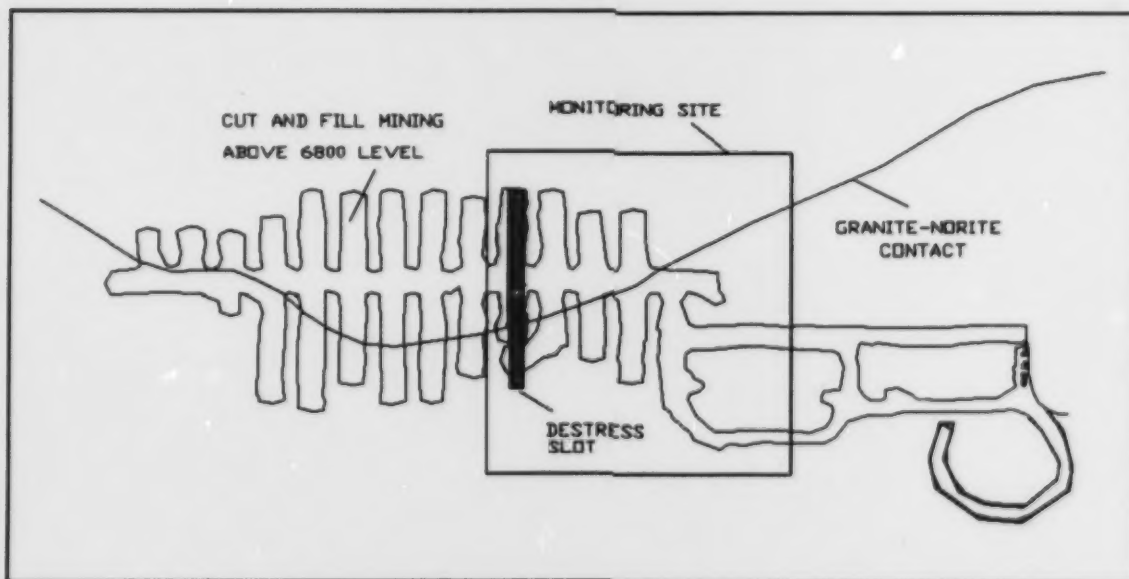


Figure 2-4 6700 Level Plan Showing The Monitoring Site

This demonstrates the necessity to realize that potential for success in any underground monitoring project is directly related to the mining activity in the area of the instrumentation installation. If the instrumentation, loggers and logger cables are exposed to the air concussions from blasting, ore haulage equipment, or active development mining equipment then the potential for damage to the monitoring equipment is high. The project will then require a substantial amount of manpower to maintain and re-install the instrumentation which will likely result in increased project cost and a substantial loss of data due to equipment damage. The most practical time at which to install monitoring instrumentation in a site is in the post development stage in areas which are remote from mobile equipment travel and protected from air blast concussion. Any attempt to conduct monitoring in active mining areas is doomed to failure.

No meaningful data was collected from 4000 VRM block which resulted in it not being used in the later calibration of the numerical code.

3.0 SUMMARY OF ROCK MASS RESPONSE TO MINING

A detailed description of the instrumentation used in this field monitoring project and the panel by panel response of this instrumentation to the progressive mining in 4500 VRM block is given later in this report. This section has been written to give the reader a summarized overview of the rock mass response to the mining in this monitoring site.

3.1 Displacement Data

The displacement instrumentation that produced the most reliable and useful information was the solid rod extensometers. These rods were anchored at 3 meter intervals along the length of boreholes that were drilled at various orientations in the monitoring site from 6600 level.

There were a total of eleven holes in which solid rod extensometers were installed and monitored (see section 4.2.1 Borehole Drilling). Of these, four were lost early in the monitoring project due to development mining or damage by mobile equipment. Of the remaining seven, one hole was drilled at 80 degrees from the horizontal, which resulted in its extensometer rods registering little displacement because the movement was primarily sub-horizontal. A second hole, which was drilled into the footwall, underwent what is believed to be movement along a footwall structure early in the monitoring program which pinched all the rods below the 15 meter depth rendering them inoperative or unreliable.

The extensometers anchored in the remaining five holes produced meaningful data until the mining advanced to the anchor location. At this point the anchors were either destroyed or demonstrated major displacement which was associated with block movement or slabbing into the excavation.

To simplify this data and eliminate the anomalies previously mentioned, the displacements from five of the holes have been represented by a single lines on a plot (Figure 3-1) of displacement versus the progressive VRM panel mining. Each line represents the average of the displacement in the anchors along the entire length of the hole. The displacements from malfunctioning anchors and movement related to structural block sliding or slabbing has not been included in the averaging for each hole.

The five lines represent holes of different orientation and dip and are located in various sections of the monitoring site. The location of the different holes are shown in plan view of 4500 VRM block in its pre-monitoring state on 6600 level (Figure 3-2). The holes have been numbered from one to five and are shown in their true plan view length. The dip and drilled length of each hole is listed in the accompanying legend.

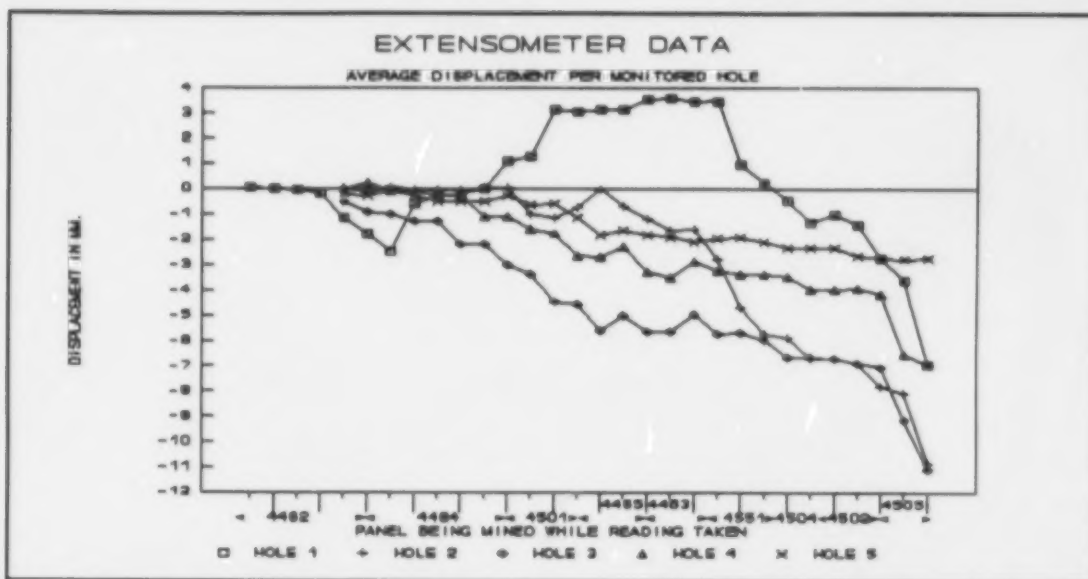


Figure 3-1 Average Displacement Over Monitoring Period

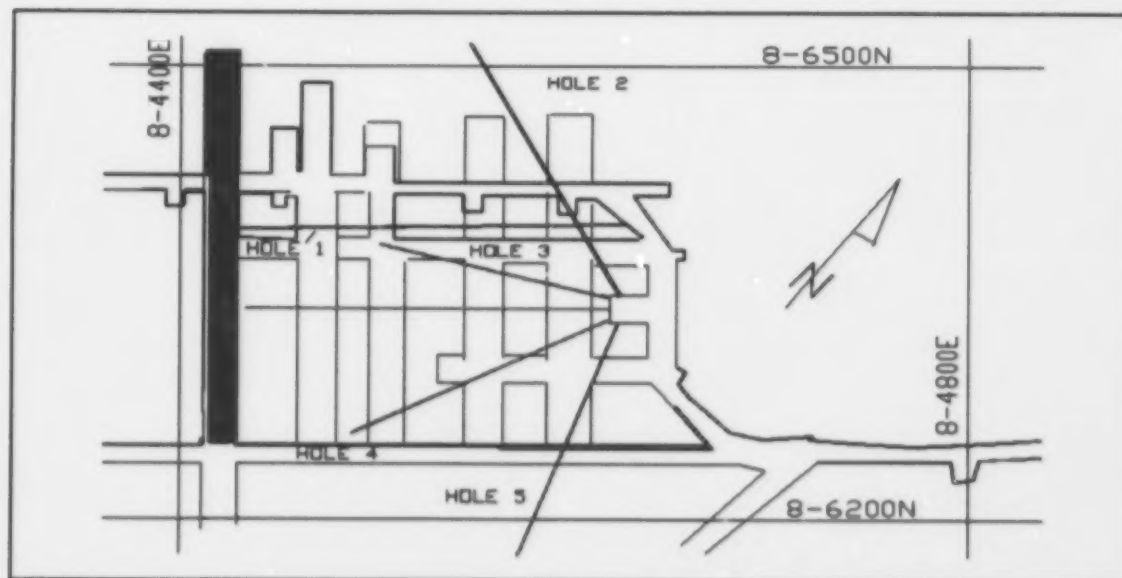


Figure 3-2 6600 Level Plan - Displacement Monitoring Holes

As Figure 3-2 shows, holes 1, 2 and 3 are located in the hangingwall side of 4500 mining block. Hole 3 is oriented 35 degrees off perpendicular to the hangingwall and will measure more of the transverse displacement and displacement in the hangingwall. Holes 1 and 2 which are parallel to the strike of the orebody, will measure the longitudinal displacement. The number one hole was drilled at 22 degrees to the horizontal making it the flattest hole. The combination of shallow dip and longitudinal orientation will result in it measuring more sub-planer displacement than the remaining hole.

The fourth hole will measure more of the displacement in the centre of the mining area while the fifth hole measures movement closer to the footwall of the mining block. Hole 6 is 25 degrees off perpendicular to the footwall and, like hole 3, measures more of the transverse displacement in the monitoring site.

3.2 Borehole Logging With a Television Camera

Boreholes were drilled throughout the monitoring site from 6600 level and left open to allow the interior of the mining block to be inspected with a television camera. The non-colour camera allowed areas of the mining block that consisted of highly fractured and broken ground to be defined along with areas that appeared to be under low stress. The joints in these low stress areas did not appear to be as tight (greater aperture) as those in the highly stressed ground. It was not possible, however, to distinguish with the camera whether the changes in the mining block were the result of rock mass failure or stress reduction in unfailed ground. Some areas of the mining block known to have gone from an intact to a failed state showed no visual indications of change with repeated camera logging.

The sections of the rock mass that were highly stressed and/or going through major stress changes could be detected by defining which sections in each borehole demonstrate small to high degrees of borehole break-out or spalling. By repeated logging of the boreholes, the areas of increased spalling indicated where the rock mass had undergone major stress change at the different stages of mining in the monitoring site. With the information obtained from the visual observation and from the instrumentation it was possible to map the migration of the stress relaxation zone associated with the progressive mining.

3.3 Stress Monitoring

The initial stress monitoring program consisted of repeated overcoring at strategic locations around the monitoring site at different stages of mining. After two years of adverse conditions not suited to this approach, it was abandoned because of the difficulty in locating a suitable location to install a triaxial stress cell close to the mining site and because of the low success rate of overcoring.

A total of three, presumably, reliable stress measurements were obtained during this period, one after the mining of each of the first three panels in the monitoring site. The magnitudes and direction of the principal stresses calculated from the measured strains during each overcoring are given in Figure 3-3 and are dated in the sequence in which they were obtained.

The overcoring approach to stress change determination in the project was replaced in year three with in place triaxial and biaxial cells used to monitor stress change in the mining site. These cells were only in place to monitor the mining of the last four panels mined in year four of the project. A typical example of the strain measured by the cells in respect to the different panels mined over that period of mining in the monitoring site is shown in Figure 3-4. The magnitudes of the stress changes measured by the different cells were below 6 MPa which made them impractical to use in the calibration of any numerical code. The precise calculation of small stress change in such a geometrically intricate, non-homogeneous, non-elastic mining area as the Creighton Mine monitoring site is beyond the accuracy of all existing numerical codes. The stress change data was useful, however, to indicate the areas and timing of stress changes in the monitoring site.

3.4 Rock Mass Response to Mining

The state of the rock mass after the destress slot was mined was determined through a combination of visual observations in the access drifts to 4500 VRM block and through running scanline and logging diamond drill core. The information obtained lead to the estimation of the location of the stress relaxation zone in the 4500 mining block prior to the commencement of the monitoring program. This is shown by the hatched area in Figure 3-5.

The stress relaxation zone referred to in this and subsequent reports was determined from a combination of stress change and displacement instrumentation readings and from visual observations made from borehole logging with a television camera and from observations made from the access drifts in the monitoring site. The term refers to sections of the rock mass that have undergone a high degree of stress relaxation during the monitoring period.

The relaxation is the result of rock mass failure or the destressing of the rock mass due to changes in the monitoring site geometry due to mining. The destressing is generally the result of a section of the rock mass being in the stress shadow of an excavated section of the orebody which has resulted in a stress reduction without rock mass failure.

The instrumentation monitoring and visual observations were not sufficient to accurately distinguish between these two destressing mechanisms. They have therefore been collectively referred to in this and subsequent reports as the stress relaxation zone.

The response of the rock mass in the monitoring site was minor during the mining of the first two panels. This is demonstrated in Figure 3-2 which shows little displacement occurring anywhere in the monitoring site during the excavation of the second panel mining; 4462 panel. The displacement associated with the excavation of 4461 panel, the first mined in the monitoring site, are not shown. The extensometers in place during that mining period showed similar displacements to those measured during the 4462 panel but they were destroyed shortly after and were replaced by those shown in Figure 3-2. The data is presented later in the report; this section offers a cumulative summary of most of the displacement readings.

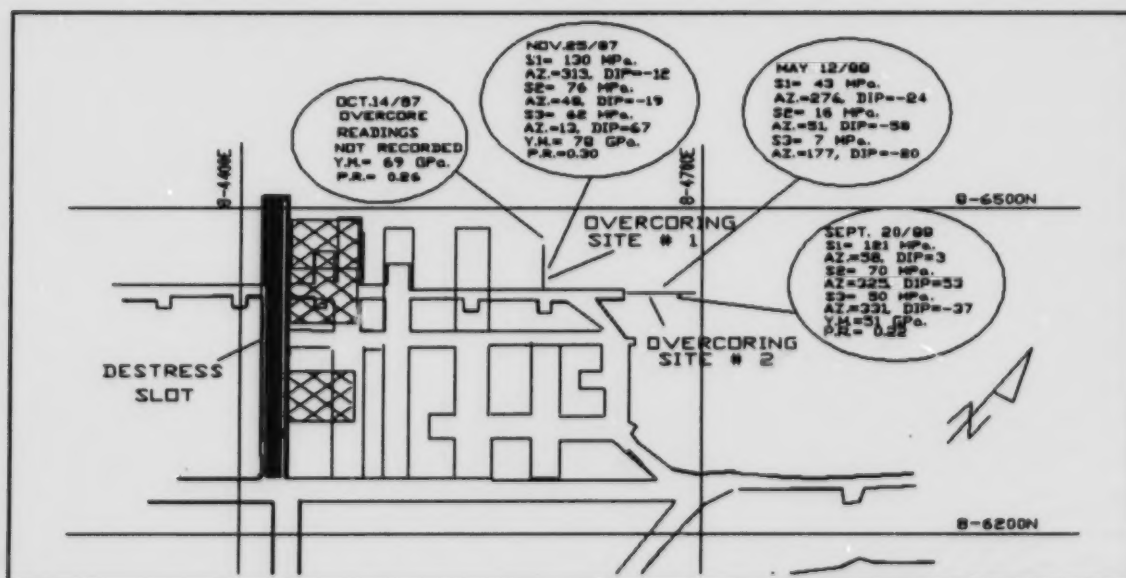


Figure 3-3 6600 Level Plan - Overcoring Stress Measurements

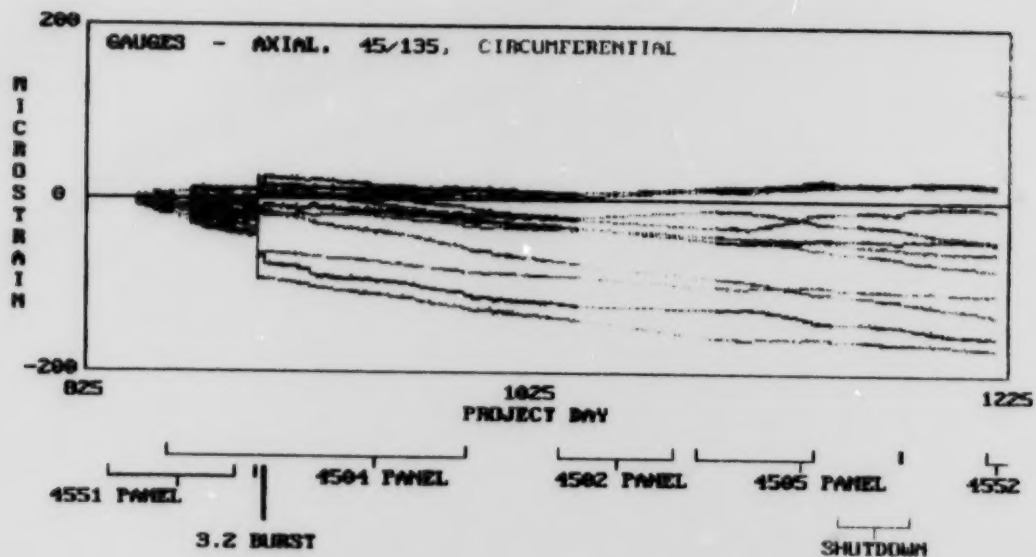


Figure 3-4 Strain Measurements From Stress Monitoring HI Cell

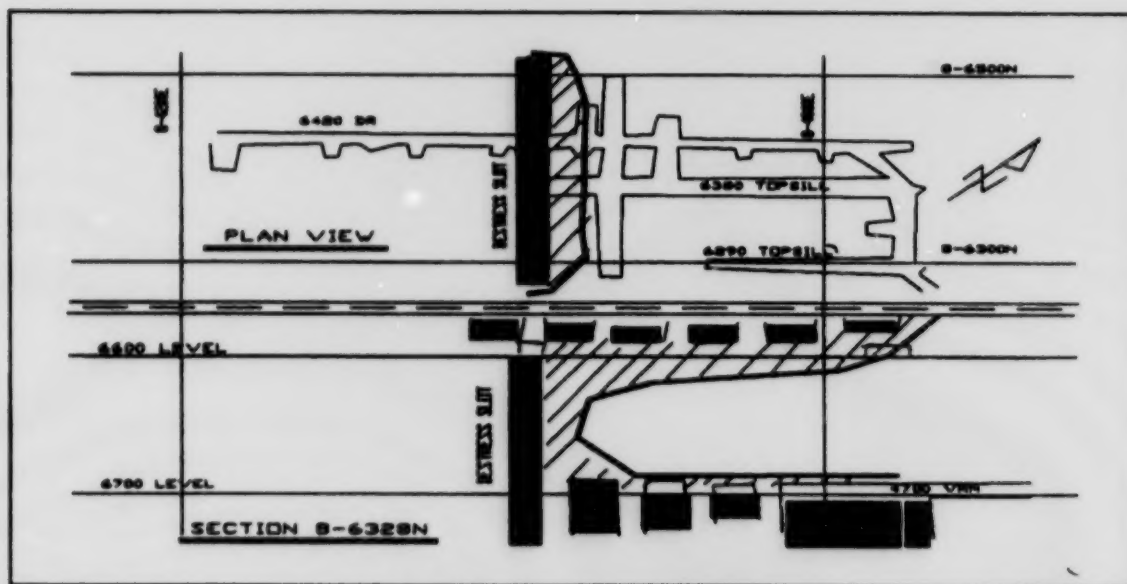


Figure 3-5 Pre-Monitoring Stress Relaxation Zone Location

The television camera logging of the rock mass inspection boreholes in the monitoring site was conducted after the mining of 4461 and again after the mining of 4462 panel. The location of the highly fractured zones and areas of high stress visually observed during the two subsequent loggings showed the stress relaxation zones to be located as shown by the hatched areas in Figures 3-6 and 3-7 respectively.

A triaxial stress cell was successfully overcored in the hangingwall on 6600 level after the mining of each of the first two panels. The measurements are from two different sites in the hangingwall, therefore, the differences are not representative of the stress changes that took place at a fixed point during the mining of the second panel. The stress data can be used, however, to attempt to calibrate a model by comparing the numerically calculated stress magnitudes at these points to the field measure values.

The mining of 4464 panel caused relatively large displacements throughout the monitoring site due primarily to the panel's proximity to the footwall. The removal of this panel produced a major stress redistribution in the monitoring site pushing the stress relaxation zone out between 4464 panel and the previous two panels mined.

Based on these displacements and on visual observations made in the drill holes of subsequently mined panels (i.e. squeezed versus non-squeezed holes) the new location of the relaxation zone was estimated as shown by the hatched areas in Figure 3-8.

The displacement measured in hole 1 (Figure 3-2) during the mining of this panel was initially away from the hole collar and towards the destress slot. The direction of displacement then abruptly changed towards the collar which was contrary to all the other holes despite their orientation.

A third triaxial cell was successfully overcored in the hangingwall on 6600 after the mining of this panel. The magnitudes of the principal stresses are substantially higher than the previous cell overcored at this same location as shown in Figure 3-3

It was during the mining of 4464 panel that the mining on the west side of the destress slot was converted from MCF to VRM mining as shown in Figure 3-8. Section 5.0 of this report should be consulted for greater detail on the progression of the mining in lower Creighton Mine in areas other than the monitoring site.

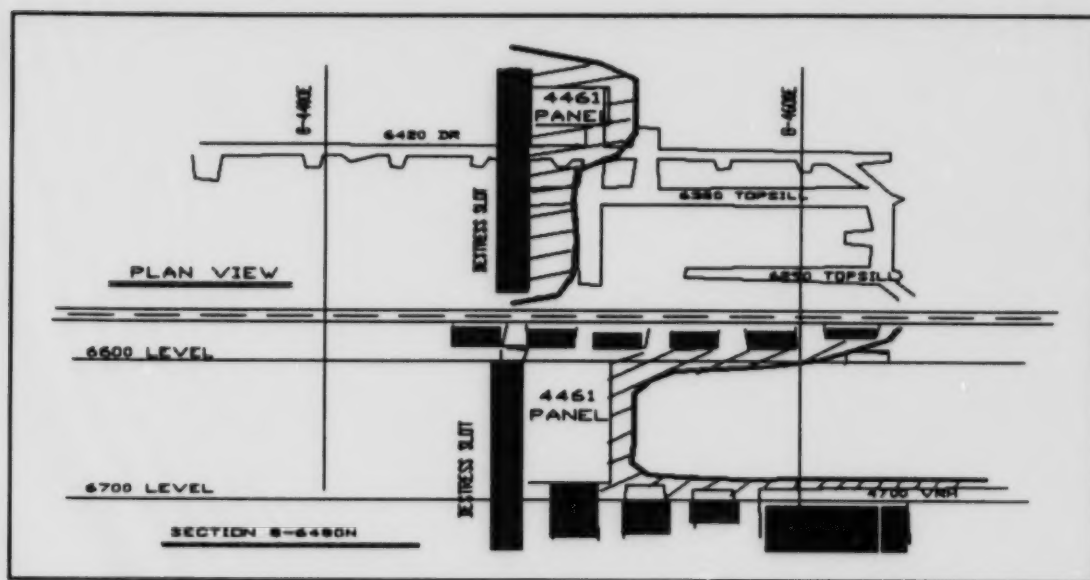


Figure 3-6 Stress Relaxation Zone Location - 4461 Panel Mining

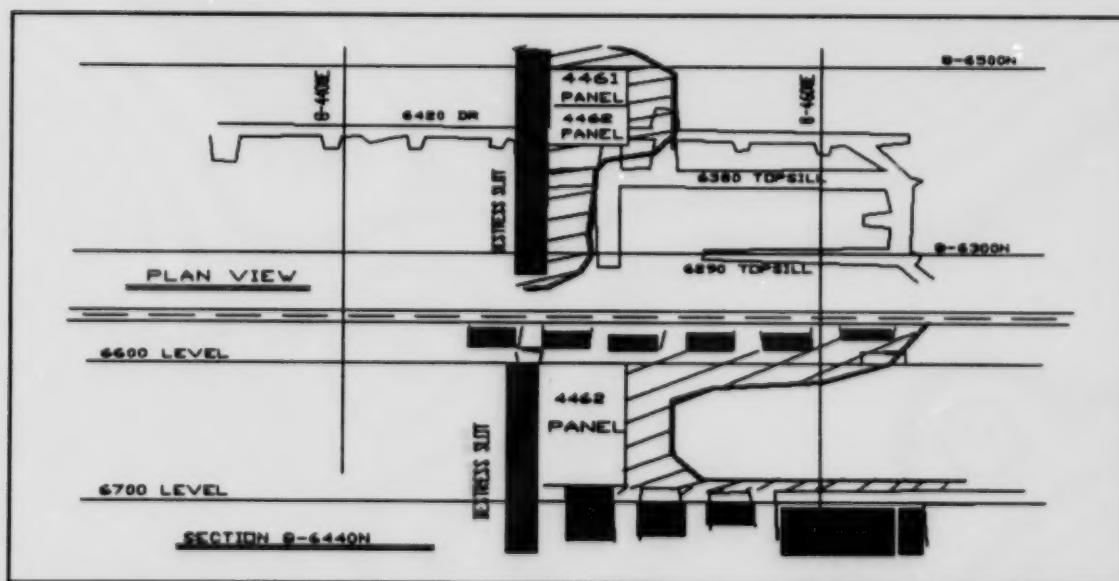


Figure 3-7 Stress Relaxation Zone Location - 4462 Panel Mining

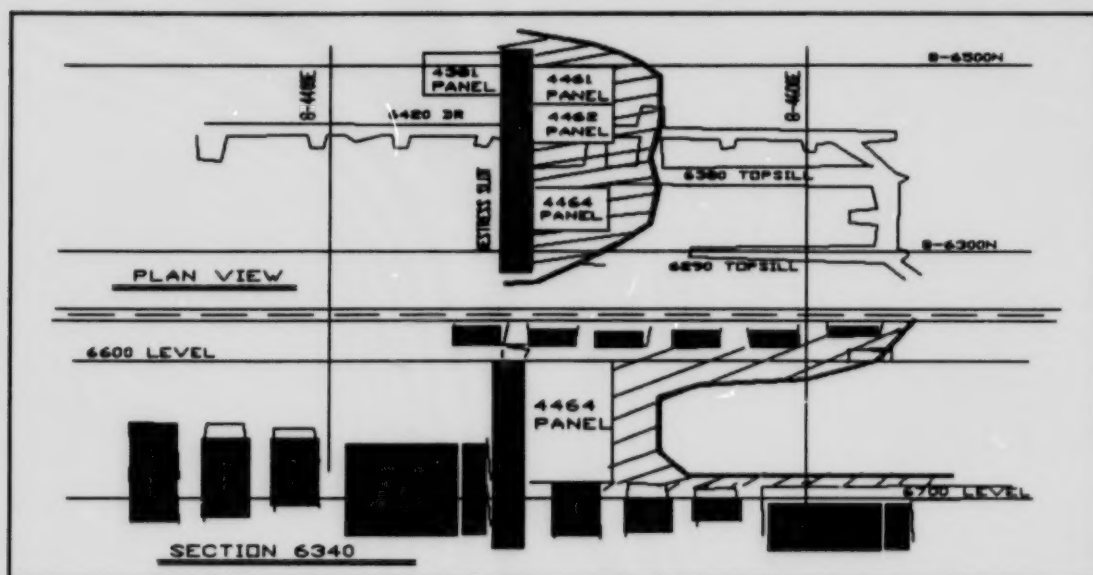


Figure 3-8 Stress Relaxation Zone Location - 4464 Panel Mining

The next panel excavated was 4501 which was located next to the hangingwall. The mining of this panel also caused relatively large displacements primarily in the area adjacent to the mining. The displacement data along with observations in the drill holes of subsequently mined panels indicated that the location of the stress relaxation zone had shifted as shown by the hatched sections in Figure 3-9.

The mining of the next two panels in 4500 VRM block caused minor displacement. Panel 4463 was mined in two halves, the first before panel 4465 and the second half after the 4465 mining. This was necessary due to operating problems during the 4463 panel mining.

The initial excavation of 4463 panel caused minor displacement in the adjacent rock mass as did the second half of this panel mining. Panel 4465 caused displacement only in the footwall. This indicated that 4463 was within the stress relaxation zone prior to its mining, which agrees with the Figure 3-9 estimate of the relaxation zone location.

This displacement also indicates that 4465 panel was on the edge of the footwall end of the relaxation zone and caused a minor shift in its location. This interpretation was reinforced by the results from the third logging with a television camera of the borehole used for inspection of the monitoring site rock mass. The combined information indicated that the relaxation zone had migrated to the location shown by the hatched section in Figure 3-10.

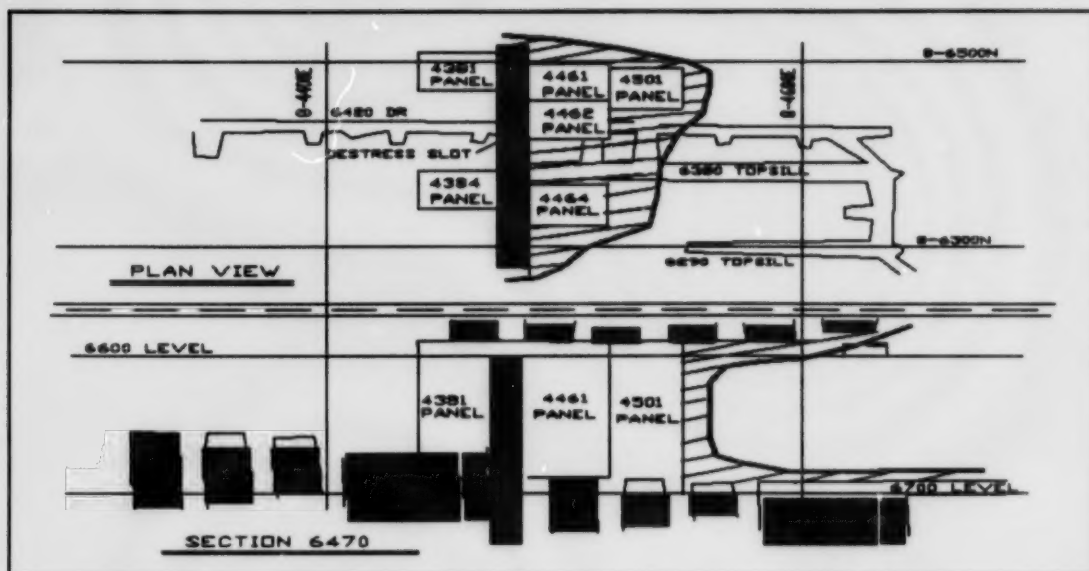


Figure 3-9 Stress Relaxation Zone Location - 4501 Panel Mining

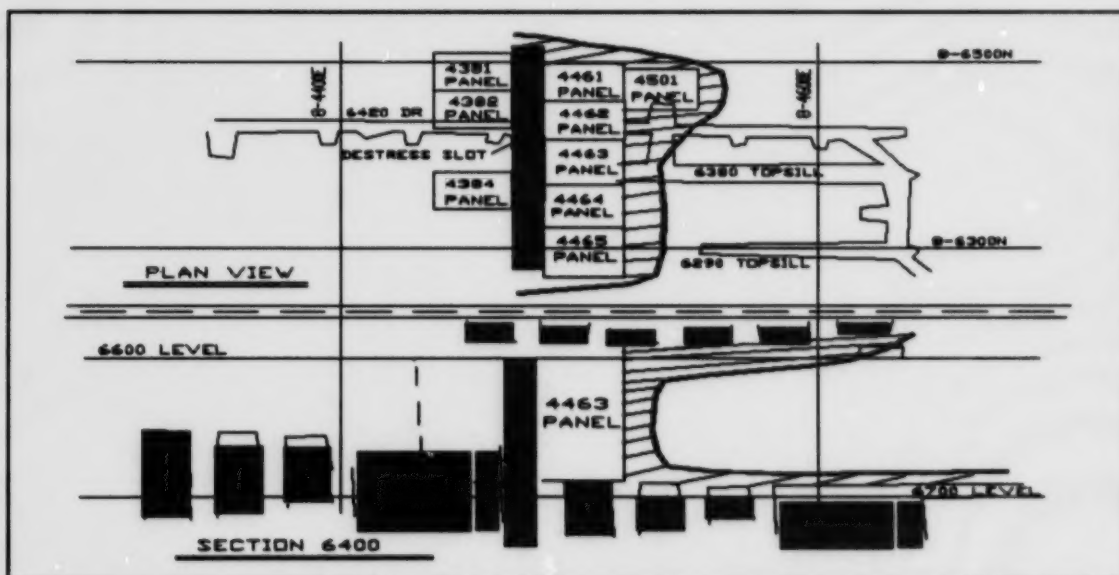


Figure 3-10 Stress Relaxation Zone Location -
4465 Panel and 4463 Panel

Panel 4551, located on the hangingwall, caused large displacements just in the area adjacent to its excavation. The removal of the crown in this panel resulted in a substantial stress change in this area which was measured by a triaxial stress cell located on 6600 level adjacent to 4551 panel. The cell measured a stress reduction of 0.4 MPa at cell location. This was followed eight hours later by a 1.7 Richter fault slip rock burst located in the footwall contact 15 meters below 6600 level which caused a 0.38 MPa stress change at the same cell location.

All of the monitoring data, together with observations in production drill holes from subsequent mining, indicated that the mining of 4551 panel triggered a stress redistribution that caused the relaxation zone to migrate to the location shown by the hatched section in Figure 3-11.

The mining of 4504 and 4502 panels caused a continuous uniform displacement of the rock mass throughout the monitoring site. The stress cells in place at mid height in the monitoring block showed no measurable stress changes associated with the mining of these two panels. This combined with visual observations made during the fourth logging of the rock mass inspection holes with a television camera indicated that both these panels were within the stress relaxation zone prior to their being mined which is consistent with the previous estimate made in Figure 3-11 of the stress relaxation zone location. The mining of these two panels did not appear to cause any noticeable change in the relaxation zone location.

The final panel mined while monitoring continued was 4505 which, like all the peripheral hangingwall and footwall panels, caused relatively large displacements. The stress change associated with this mining indicated that its excavation caused a relatively large stress redistribution in the footwall area adjacent to the panel mining.

This combined information indicated that the 4505 panel mining caused the stress relaxation zone to migrate as shown by the hatched areas in Figure 3-12.

The above summary of the rock mass response to the mining in 4500 VRM mining block gives a quick overview of the monitoring program and the analysis of the data collected over the four and one-half year duration of the project.

The following sections give a detailed explanation of the work that has been carried-out for the length of the project. To use the results from this study to calibrate any numerical code will require reading the detailed section on the mining sequence to properly represent the progressive changes in the mining geometry that took place over all of lower Creighton Mine during the monitoring period.

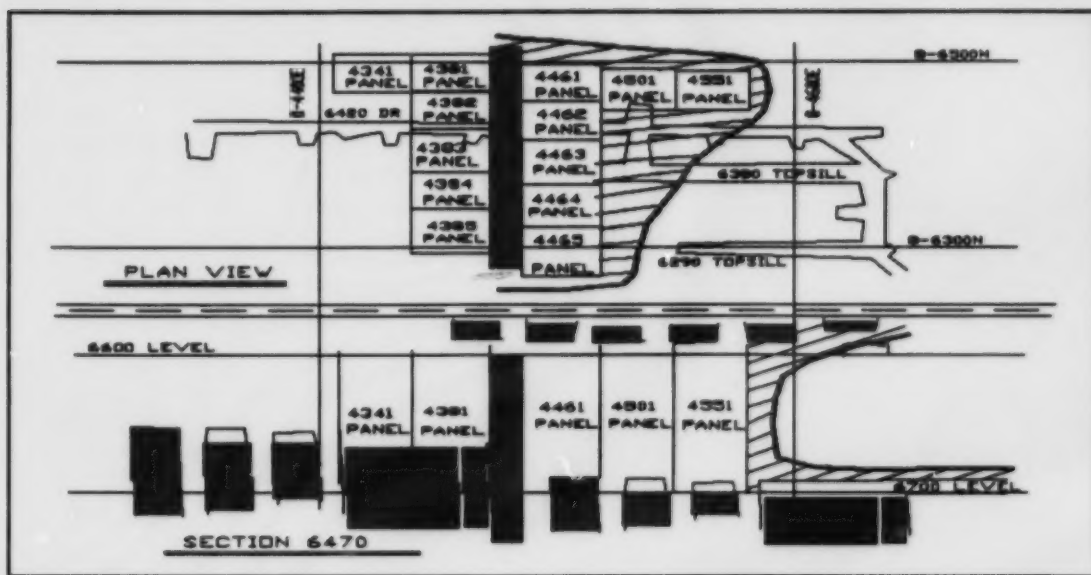


Figure 3-11 Stress Relaxation Zone Location - 4551 Panel Mining

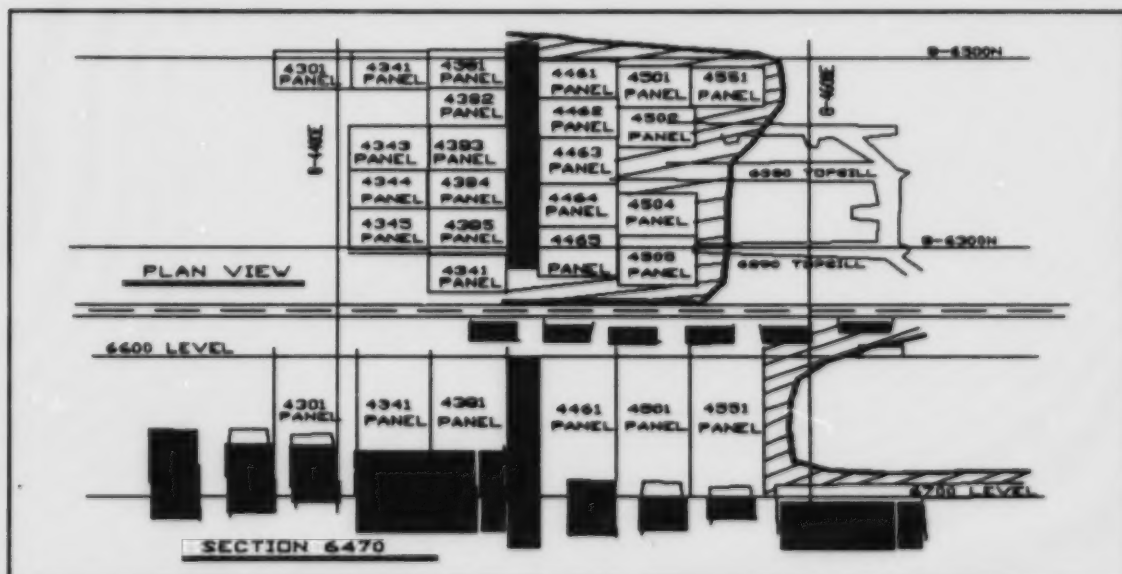


Figure 3-12 Stress Relaxation Zone Location - 4505 Panel Mining

4.0 THE FIELD MONITORING PROGRAM

The purpose of the monitoring program was to collect field data associated with the rock mass response to the progressive bulk mining in 4500 VRM block for use in the calibration of the numerical codes being written as part of this project. The monitoring program was, consequently, aimed at defining the areas of major change associated with each stage of mining rather than the precise measurement of the magnitude and direction of change. This approach was taken because it is unreasonable to expect any numerical code to be able to reproduce the changes measured at a point in the rock mass in as complicated a geometry as exists in the 4500 mining block.

4.1 Initial Site Investigation

The first year of the field monitoring program was spent on the initial structural evaluation in the monitoring site and the drilling of boreholes necessary for the installation of the instrumentation and for rock mass inspection. The second, third and fourth years were concentrated on data collection and analysis.

Prior to the commencement of the actual field monitoring an attempt was made to determine the general geotechnical rock mass properties of the monitoring sites at Creighton Mine. The field stresses at this depth were defined from overcoring work performed by CANMET several years prior to this project (Herget, G., 1987, 1977, 1975).

$$\sigma_1 \text{ (MPa)} = 1.8 \times \text{depth} + 10.83$$

oriented along the strike of the orebody;

$$\sigma_2 = \sigma_3 = 1.29 \times \text{depth}$$

and orthogonal to σ_1 .

The strength properties of the intact materials that make up the footwall, hangingwall and mining area were obtained from a combination of previous compression and Hoek cell tests done on various diameter cores over the last several decades and testing conducted a part of this project (hangingwall norite, UCS=155 MPa, YM=79 GPa, PR=0.29, COH=36 MPa., F/A=40 DEG; footwall granite/gabbro, UCS=240 MPa, YM=55 GPa, PR=0.25, COH=33 MPa, F/A=35 DEG.; ore, UCS=130 MPa, YM=68 GPa, PR=0.25; COH=37 MPa, F/A=40 DEG.; cemented backfill, UCS=0.25 MPa, YM=24 MPa, PR=0.20, COH=0.01 MPa, F/A=33 DEG.).

An extensive scanline survey was conducted in year one in and around 4500 VRM mining block on both 6600 and 6700 levels. The purpose of the work was to define the major joint sets that existed

in this general area of Creighton Mine and to determine the C.S.I.R. Rock Mass Rating (R.M.R.) and Q value from the NGI system of Rock Mass Classification System. The location of each scanline run is shown in Figures 4-1 and 4-2 and a log of the results and the general rock mass properties used in the Rock Mass Classification and later numerical modelling of the site can be found in floppy disk data files.

At each location, scanlines were run in both a horizontal and vertical direction on the drift walls to reduce the bias that would be associated with joints oriented parallel to the scanline tape direction. A lower hemisphere equal angle contour plot created from the scanline data collected in the footwall is shown in Figure 4-3. The contour plot shows the dip direction of the poles of the two major joint sets which exist in this section of the mine.

These joint sets are approximately parallel to the direction of the major and intermediate (horizontal) principal stresses at this depth and combined with the rock mass properties of the footwall, hangingwall and ore zone sites to produce Rock Mass Ratings of 66, 59 and 55 respectively. The Q values obtained using the NGI system were 12, 6 and 3.5 respectively. These ratings are low for the hangingwall and ore zone rock mass because they were obtained from scanlines in the fractured mining access drifts on 6600 and 6700 levels. The Creighton Mine ore and hangingwall are known, from similar work conducted previously in less disturbed mining areas, to both have R.M.R. values of 65. The footwall value agrees with this previous work because it was obtained from scanline run in areas more remote from the mining.

The scanline data allowed the location and orientation of nine major fractures that showed signs of past movement to be defined. These nine fractures are plotted in Figures 4-4, 4-5 and 4-6, showing their locations as they intersect 6600 level, mid height in the monitoring site and 6700 level respectively. The three plots demonstrate the potential for major block structures that could be mobilized during the mining of 4500 VRM mining block.

The information obtained from the scanline work, diamond drill core logging and from general observations made underground was used to estimate where the stress relaxation zones around the existing openings were located prior to monitoring. The estimated location of the relaxation zone shown by the hatched lines in Figure 4-7 indicates that it extends approximately 9 meters into 4500 mining block.

The drilling of the I.T.H. holes for the mining of the VRM panels mined next to the destress slot confirmed that this section of ground was indeed stress relaxed. The drilling was completed without any problems and there was no indication of borehole

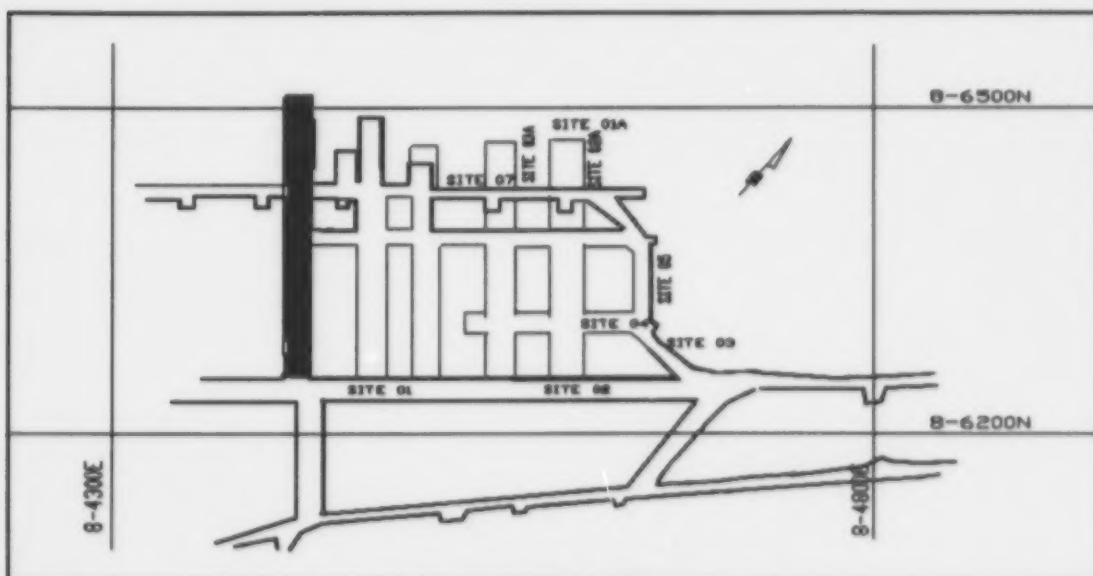


Figure 4-1 6600 Level Plan - Scanline Locations

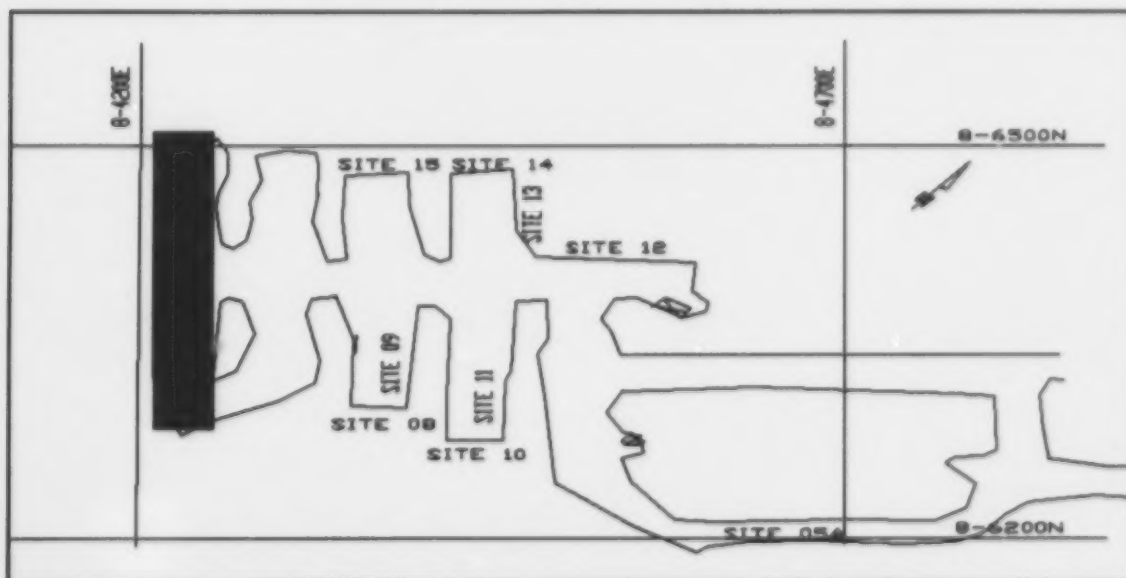


Figure 4-2 6700 Level Plan - Scanline Locations

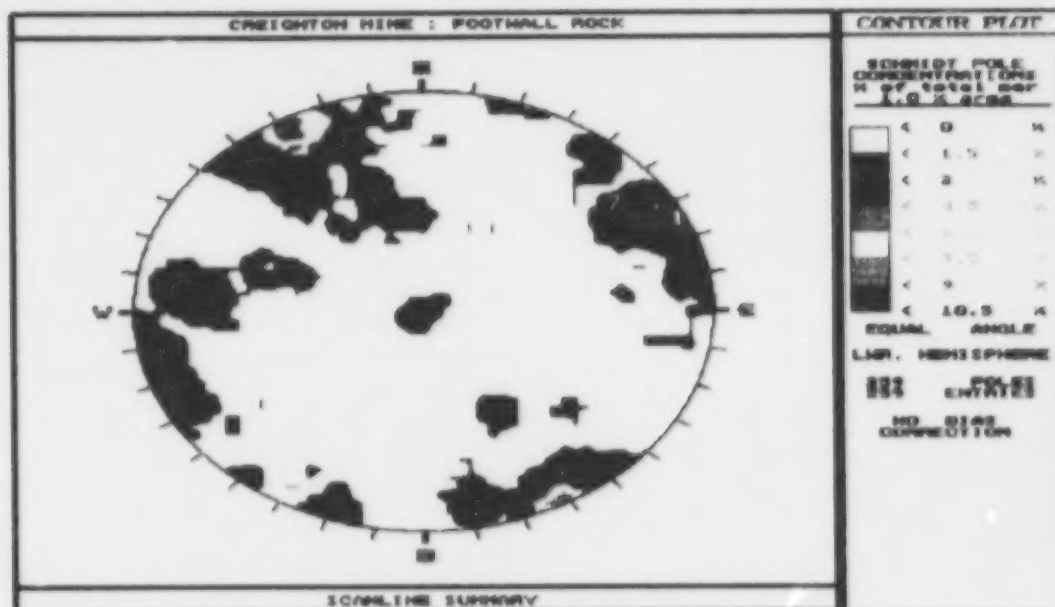


Figure 4-3 Contour Plot of Joint Sets

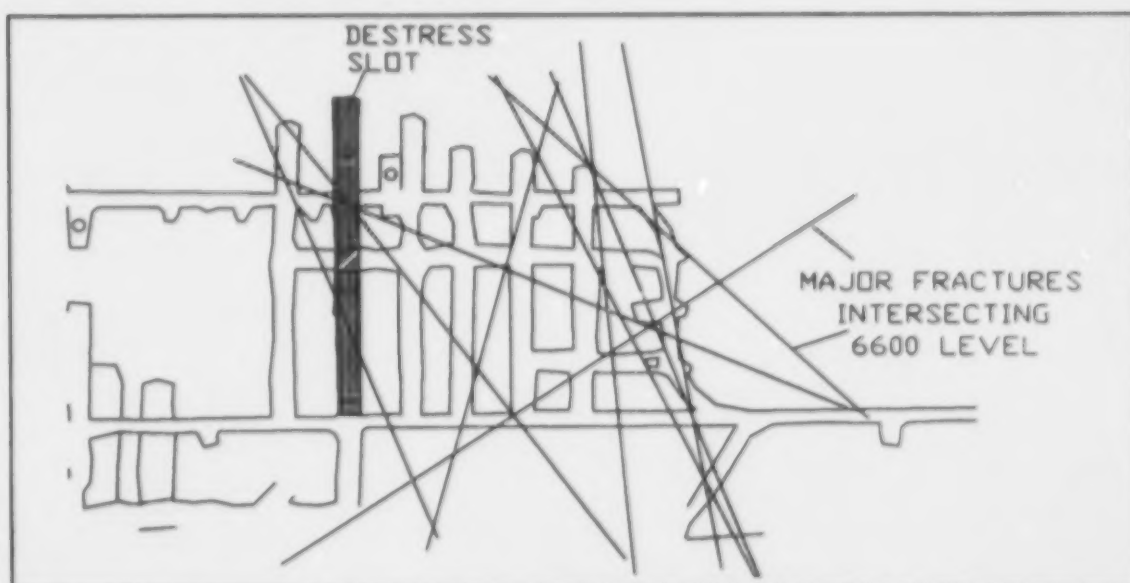


Figure 4-4 Major Fractures Intersecting 6600 level

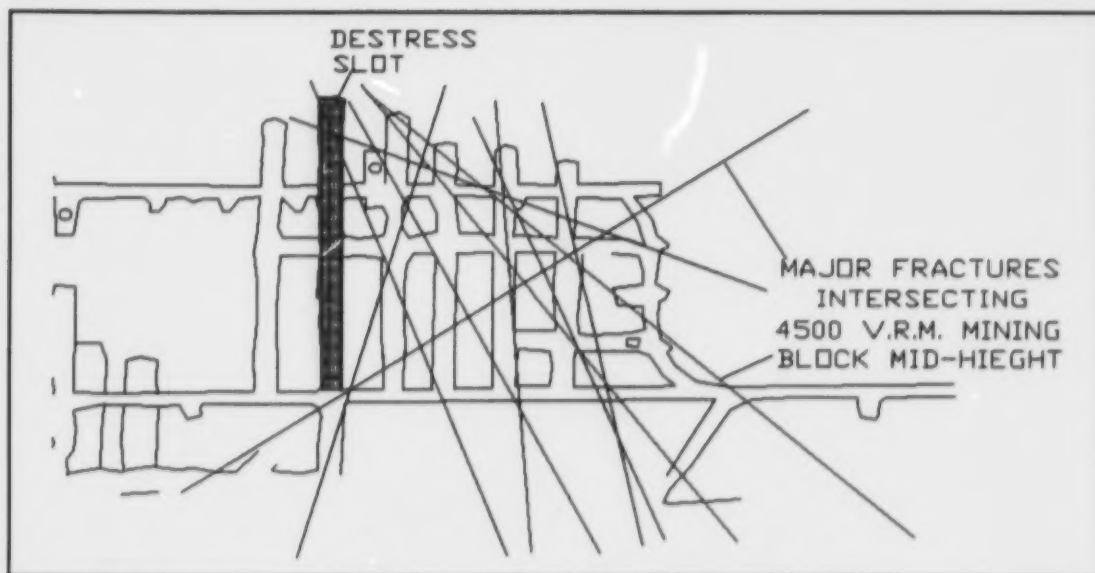


Figure 4-5 Major Fractures Intersecting Mid Mining Block

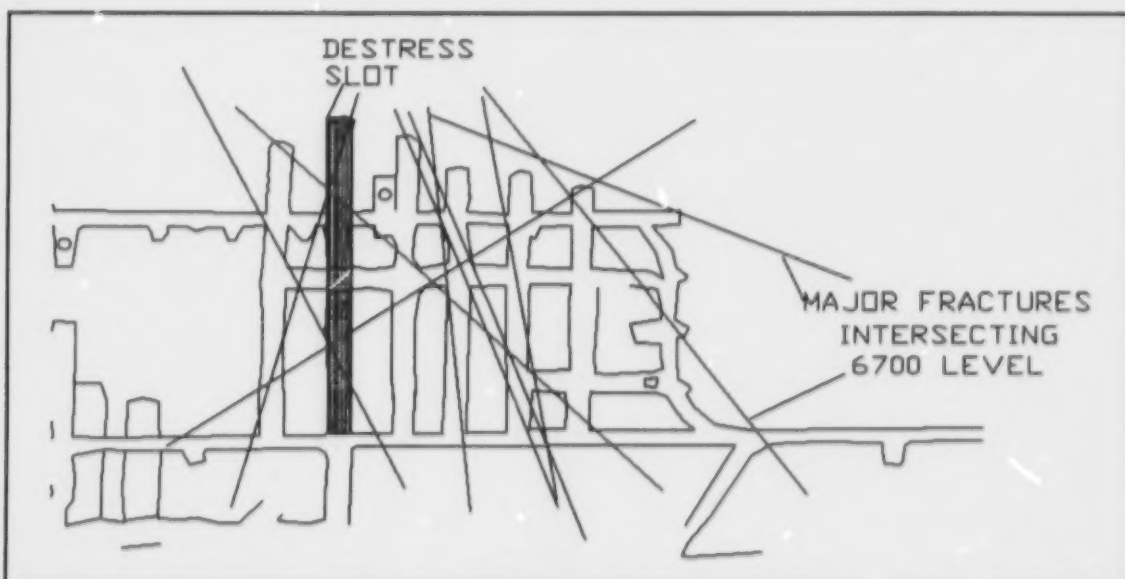


Figure 4-6 Major Fractures Intersecting 6700 Level

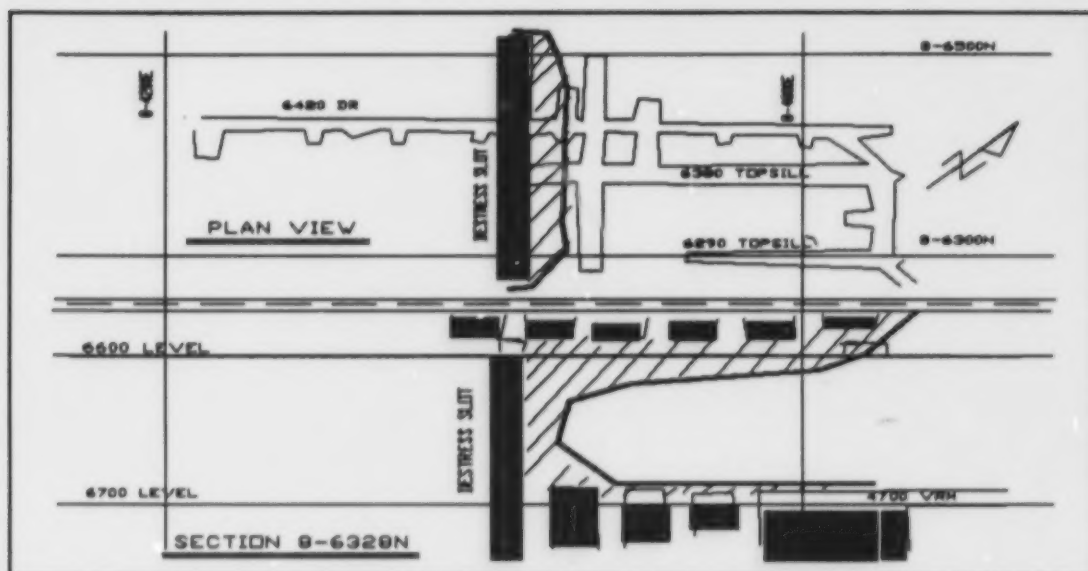


Figure 4-7 Pre-Monitoring Stress Relaxation Zone Location

breakout or spalling in any of the holes drilled in any of these panels which, at this depth, generally indicates a low stress area.

4.2 Instrumentation

The monitoring program was aimed at three major measurements of rock mass change; field stress changes, rock mass displacements, and migration of the stress-relaxation zone. A wide variety of monitoring techniques and monitoring instrumentation was used to obtain this information from 4500 VRM mining block.

4.2.1 Borehole Drilling

The boreholes that were drilled in year one of the project for the purpose of instrumentation installation and rock mass inspection are shown in plan and sectional views in Figures 4-8 to 4-18. The intended use of each of the 6 inch diameter holes is indicated in the legends on the drawings (i.e., holes containing grouted extensometers and inclinometer casing for ground displacement measurements are labelled INCL.-EXT., open holes for ground inspection by a borehole television camera, are labelled VIS. INSP.).

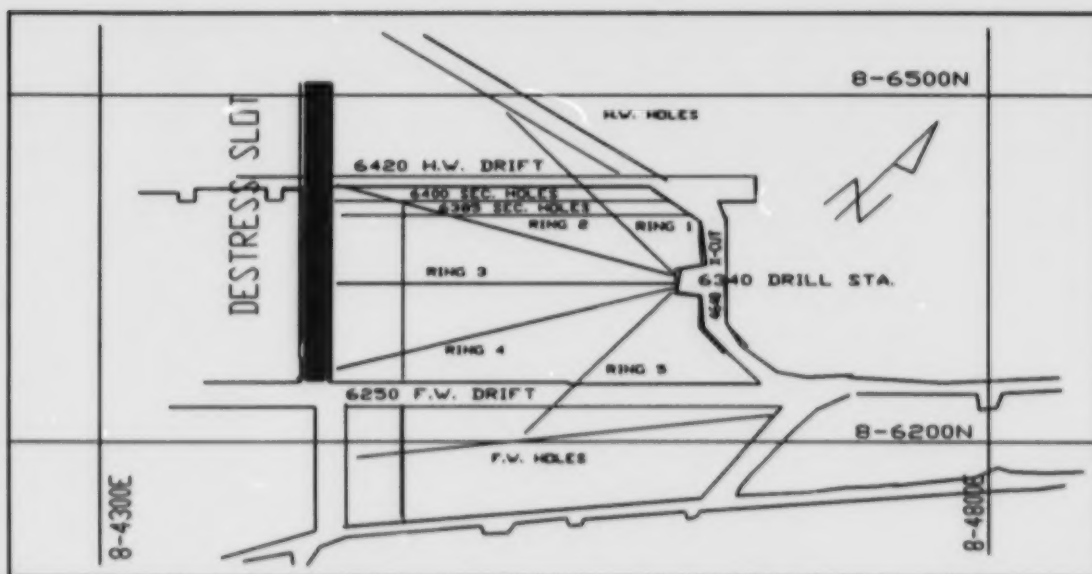


Figure 4-8 6600 Level Plan - Monitoring Hole Drill Rings

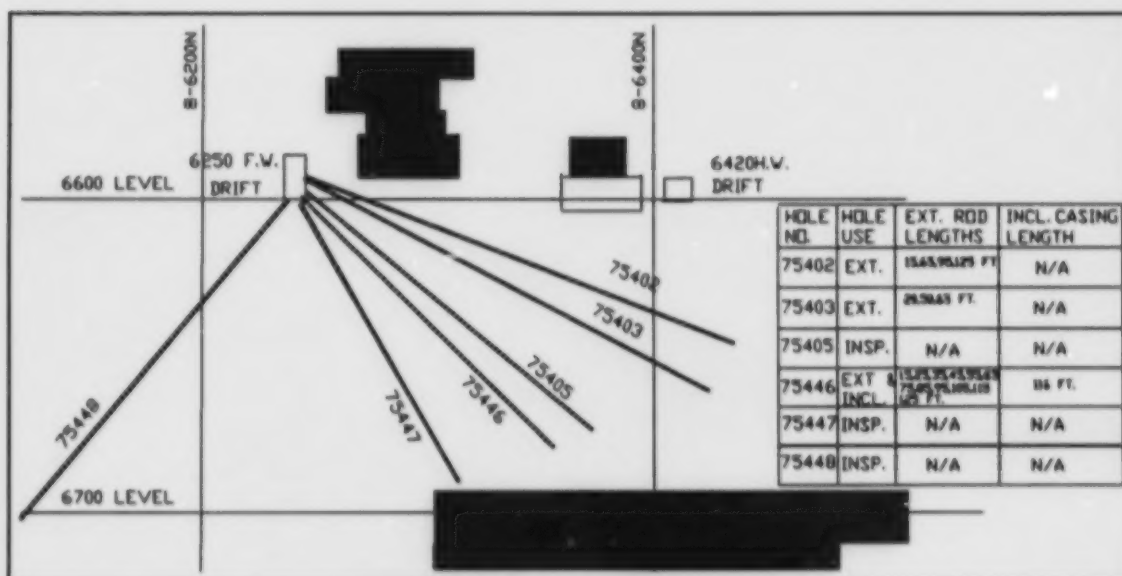


Figure 4-9 Monitoring Holes Drilled on Section 4469

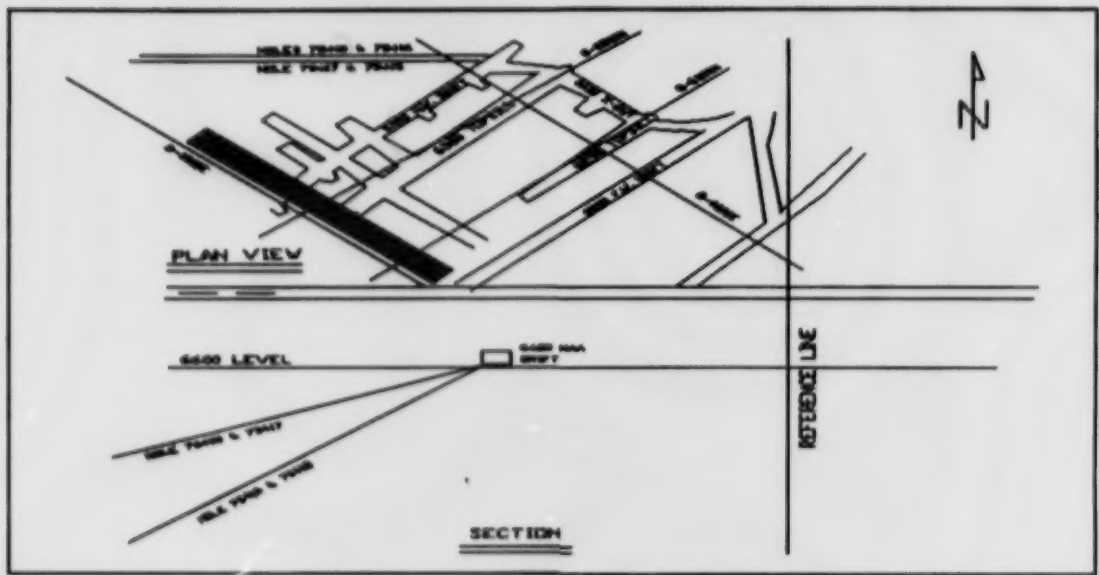


Figure 4-10 Hangingwall Rock Mass Inspection Monitoring Holes

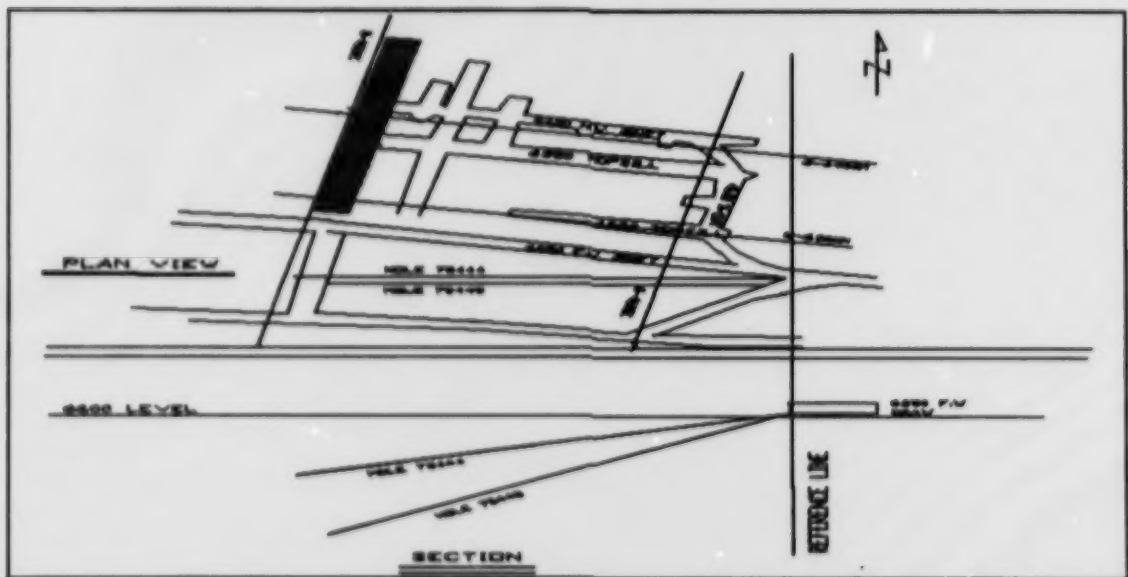
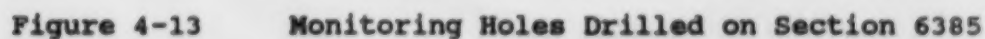
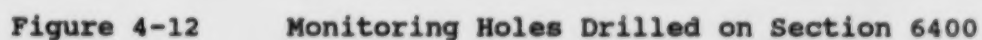


Figure 4-11 Footwall Rock Mass Inspection Monitoring Holes



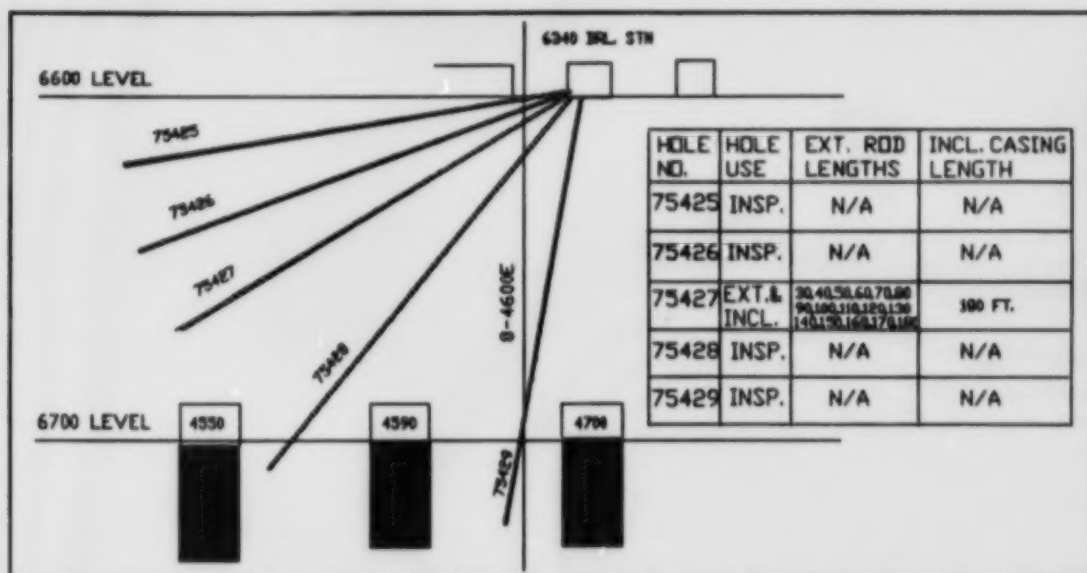


Figure 4-14 Monitoring Holes Drilled in Ring 1

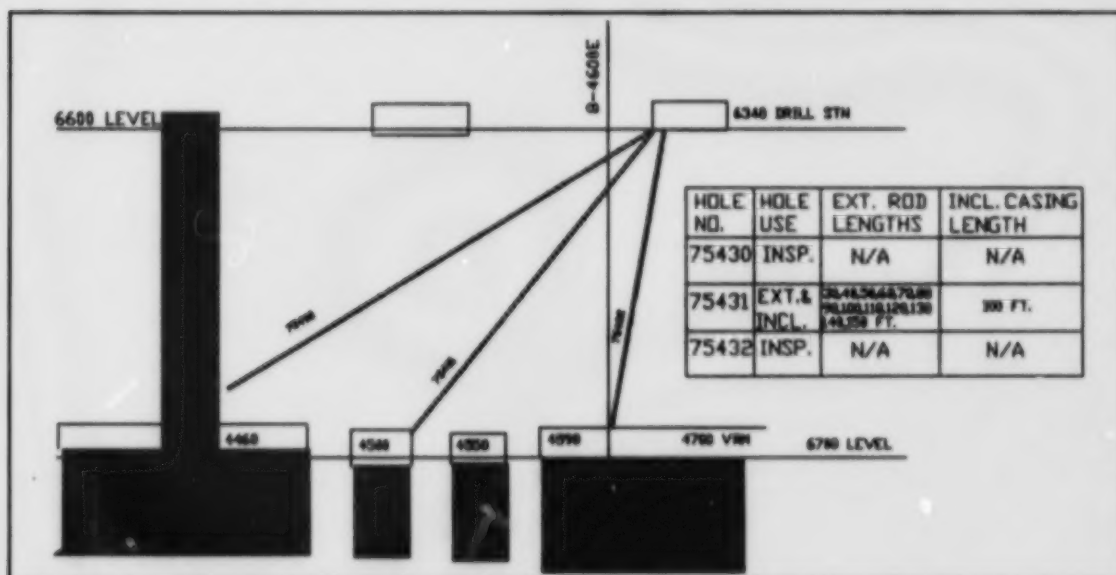


Figure 4-15 Monitoring Holes Drilled in Ring 2

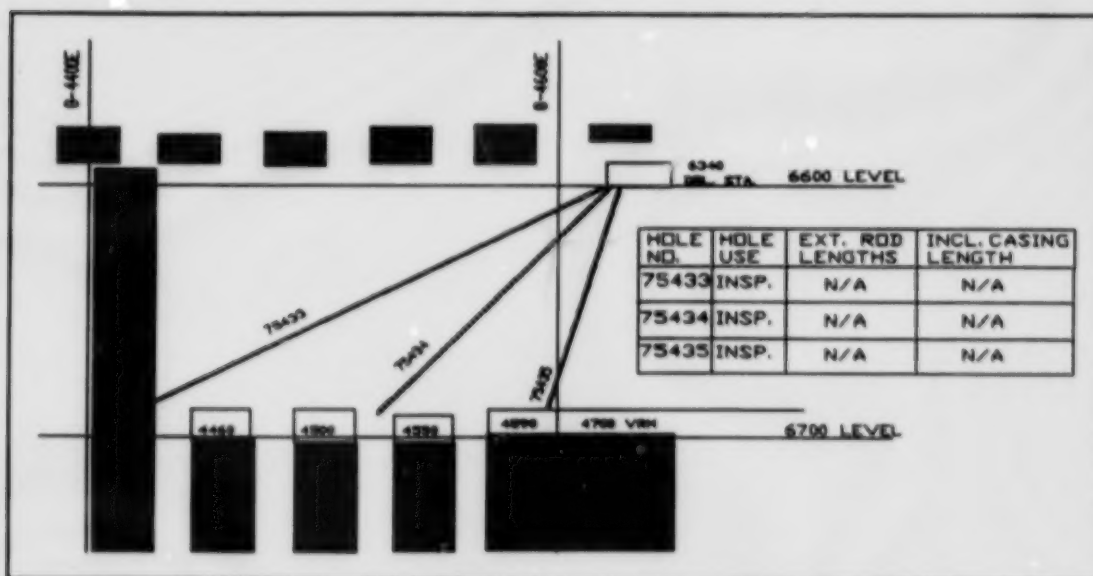


Figure 4-16 Monitoring Holes Drilled in Ring 3

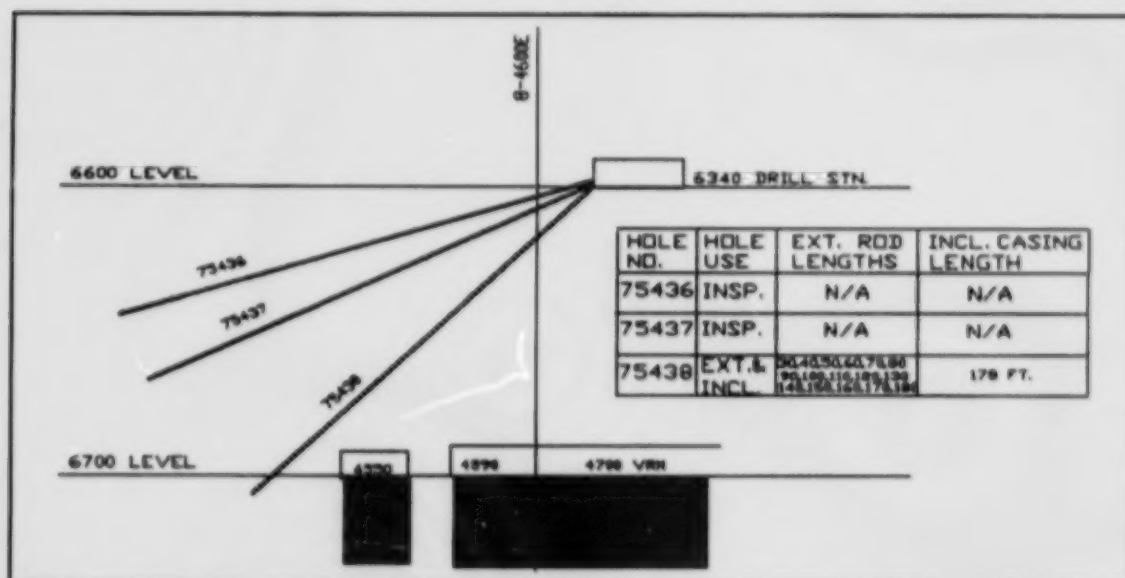


Figure 4-17 Monitoring Holes Drilled in Ring 4

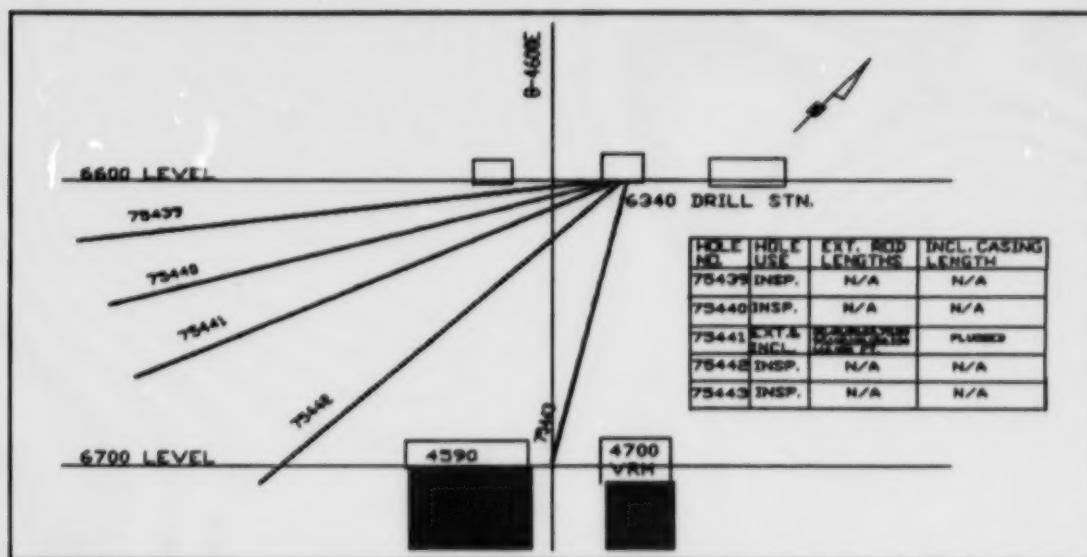


Figure 4-18 Monitoring Holes Drilled in Ring 5

4.2.2 Borehole Logging

One of the primary objectives of the field investigation was to locate the initial stress relaxation zones in and around the monitoring site and then to map their migration as mining progressed. This was accomplished, after the mining of the destress slot and the first panel in 4500 VRM block (4461 panel) through a combination of scanline work in the access drifts to the monitoring site, the logging of diamond drill core from several holes drilled into the site early on in the project, and through general observations made in the monitoring site.

The locations of these diamond drill holes is shown in Figures 4-19, 4-20 and 4-21 and the respective logging data is given in the data files on the accompanying floppy disks.

Once the drilling of the boreholes in the monitoring site was completed, which was not until after the mining of 4461 panel in 4500 block, a method of borehole logging with a Knopafex SCM-1.5 3 inch diameter mini television camera and MCC-10 control unit was employed to locate these zones. The holes were logged to determine the location of major fractures in the mining block, the areas of highly fractured ground and orientation and extent of spalling in the borehole walls. From these extremely useful visual observations, which were made at four different stages of mining over the duration of the project, the changing location of the stress relaxation zone was estimated.

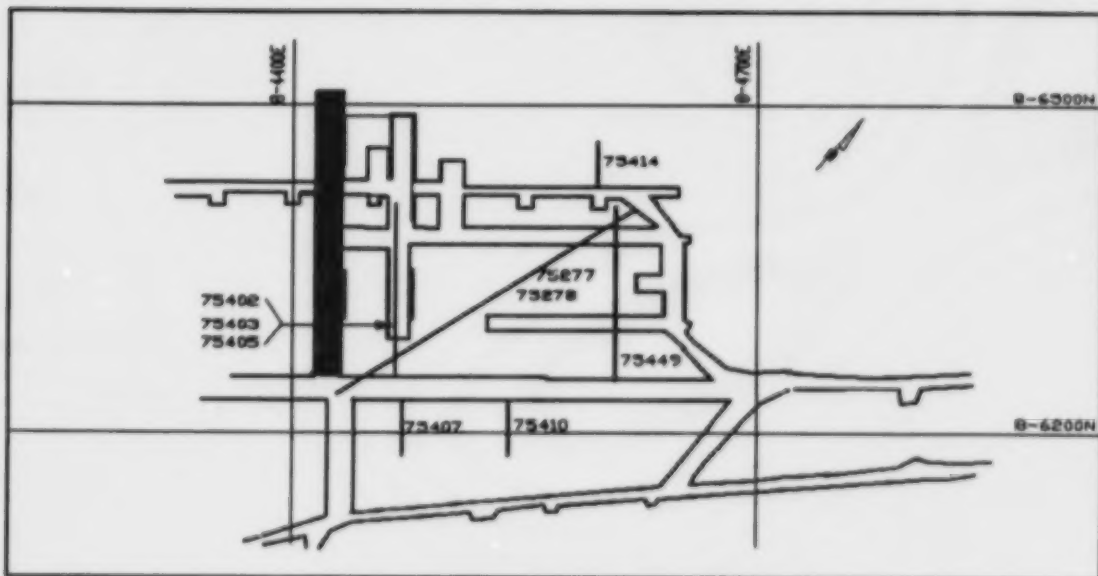


Figure 4-19 6600 Level Plan - Diamond Drill Rings

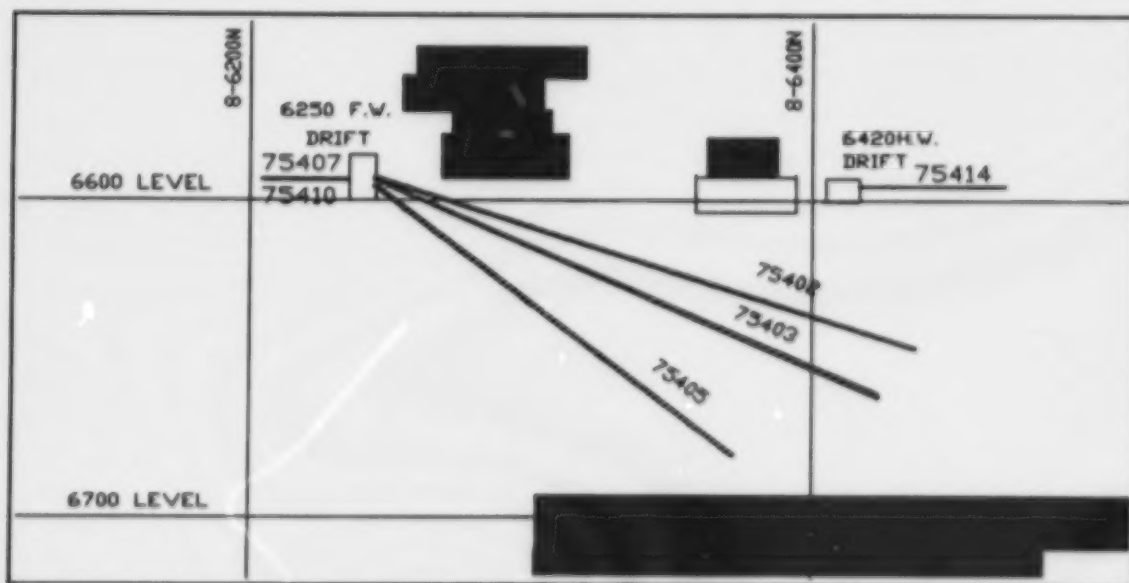


Figure 4-20 Diamond Drill Holes Drilled on 4469 Section

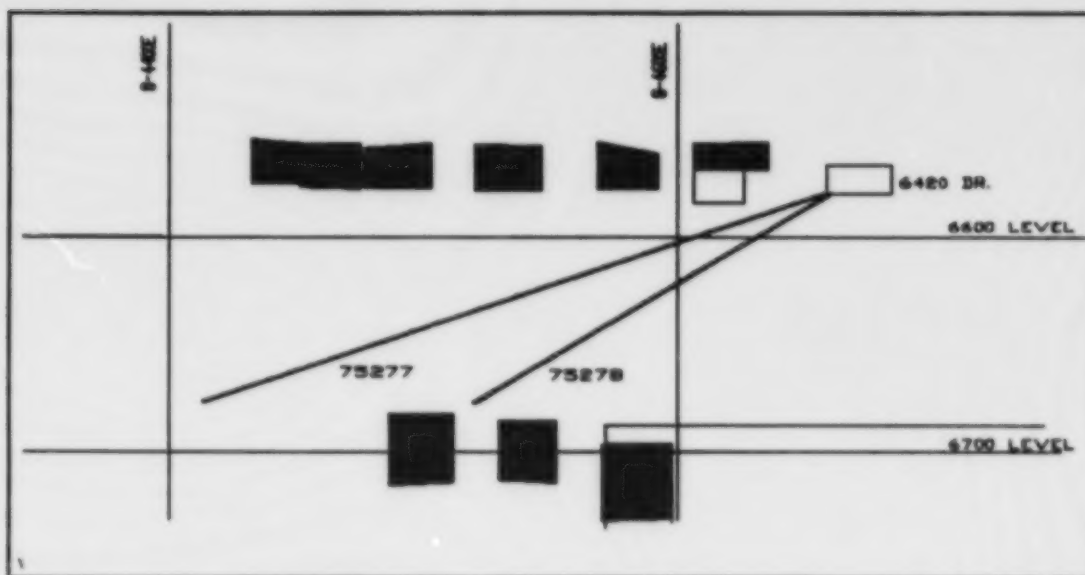


Figure 4-21 Diamond Drill Holes Drilled Diagonally Across Site

4.2.3 Microseismic Monitoring

An extensive array of microseismic accelerometers and geophones have been in place at Creighton Mine for many years. Attempts were made to use the source location data for the seismic events around the monitoring site to try and better map the migration of the stress relaxation zone with the progression of the mining. The seismic activity is associated with stress change and displacement in the mass and it was hoped that the areas of high seismic activity would coincide with the areas undergoing stress relaxation.

The seismic events that were generated in the area surrounding the monitoring site during the mining of several of the VRM panels was analyzed. These specific panels were known to have caused relatively high stress redistribution and the migration of the stress relaxation zone. The increase in the number of seismic events did coincide with the timing of the measured stress changes in the monitoring site but the source locations of the events did not show a clear relationship between event location and relaxation zone migration.

This potential relationship may be more clearly defined by an improved source location algorithm which is being incorporated into the mine microseismic source location software or by capturing the full wave form and doing detailed analysis on the event data. Both options will be available at Creighton Mine but not in time to be utilized as part of this project.

The source locations for the more major seismic events over the duration of the monitoring project are included in the floppy disk data files.

4.2.4 Mass Displacement

A variety of instrumentation was used to measure mass displacement in the monitoring site. Aside from the multi-point solid rod extensometers and vertical borehole inclinometer that were used to measure displacement in the boreholes, a tape extensometer, closure meters and single point extensometers were used to measure drift closure and displacement in the drift ceiling.

4.2.4.1 Closure Meters

The closure meters which were installed on 6600 level were unfortunately damaged several times early on in the project. They were eventually abandoned without collecting any meaningful data due to the difficulties encountered in trying to protect them from the active drift development and ore transport in the area.

4.2.4.2 Single Point Extensometers

The single point extensometers or ground movement monitors, which were installed in the drift ceilings on 6700 level, were also abandoned for similar reasons. The cables that attached to the linear potentiometers of the extensometers were constantly being damaged by mobile equipment movement or blasting on the level. The difficulties encountered in maintaining the units for any significant length of time resulted in no meaningful data being collected from the instrumentation.

4.2.4.3 Tape Extensometer

The tape extensometer was used to measure drift closure on both 6600 and 6700 levels. The location of the monitoring stations on both levels is shown in Figures 4.22 and 4.23. The stations on 6700 level were eventually lost in year three of the project due to the need to backfill that section of the level because of poor ground conditions. The level was later re-developed but new stations were not established due to the lack of closure being measured at the other stations.

Both 6600 and 6700 levels are below and above major mined out areas and are consequently located in areas of highly relaxed ground. These areas, therefore, did not undergo major stress or displacement changes as the mining progressed in the monitoring

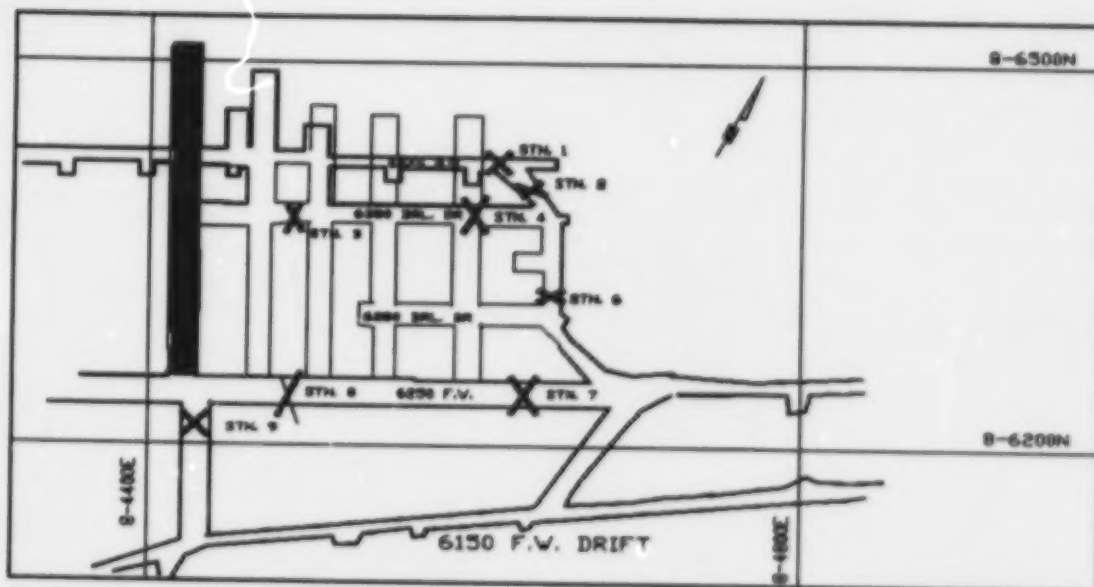


Figure 4-22 6600 Level Plan - Tape Extensometer Stations

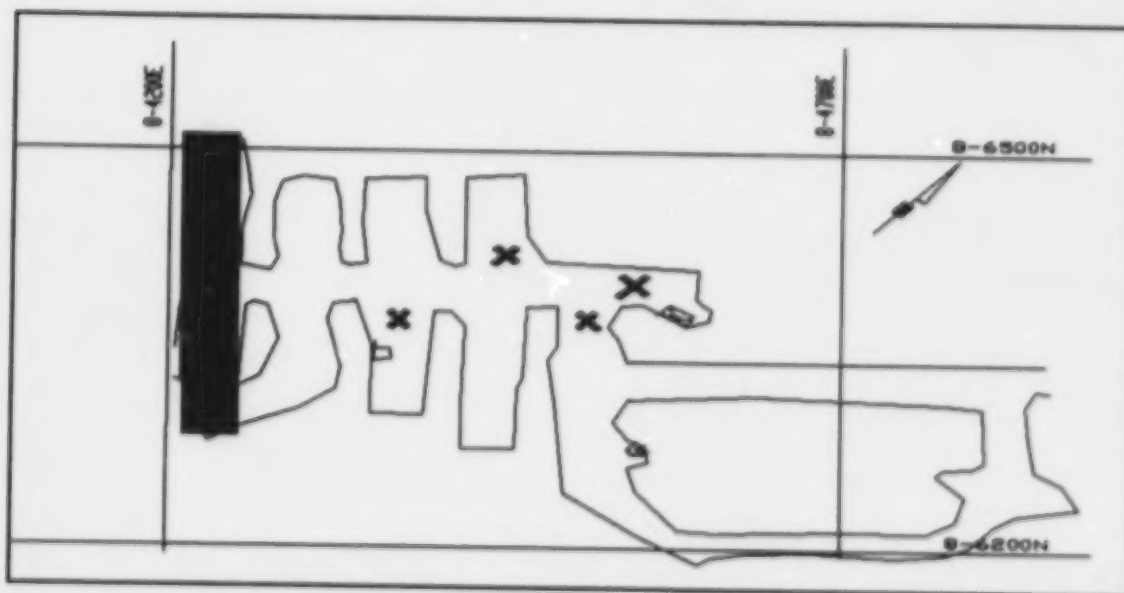


Figure 4-23 6700 Level Plan - Tape Extensometer Stations

site. This was reflected by the tape extensometer readings which showed little to no movement within the accuracy of the instrument (plus or minus 0.3 mm.) at all the monitoring stations. Plots of the drift closure measured at each of the four stations monitored over the duration of the project on 6600 level are given in Figures 4-24 to 4-27.

4.2.4.4 Multi-Point Solid Rod Extensometers

The multi-point solid rod extensometers were grouted into specific boreholes at three meter intervals as indicated in Figures 4-8 to 4-18. Several of these holes also contain inclinometer casings which allow both axial and planer displacements to be measured by the combined instrumentation.

The majority of extensometer rods were manually read with vernier callipers while a small number were equipped with linear potentiometers and continually read by datalogger. The data collected by the logger, which has been included on the floppy disk data files, is unreliable due to problems encountered with the loggers and the corrosion of the potentiometer arms and cables. Consequently, the data from the manually read extensometers only has been used in the subsequent analysis of the mass response to the progressive mining in the monitoring site. Figures 4-28 to 4-58 show the displacement and strain measured in each borehole at various depths at the different stages of mining in the monitoring site. The sign convention used assumes positive displacement to be movement towards the borehole collar while negative is away from the collar and positive strain is expansion with negative strain being compression.

4.2.4.5 Inclinometer Probe

The biaxial inclinometer probe used in this project was designed for vertical holes and decreased in accuracy as the angle of the holes approach horizontal. This combined with contamination of the inclinometer casing with the cement slurry used to grout the holes (Landriault, 1989) produced a varied accuracy in the readings obtained from hole to hole.

To compensate for this varied inaccuracy, a series of repeatability tests were conducted several times in each hole to determine the expected accuracy of the readings at any given depth in any given hole. This expected accuracy was then used to filter out actual movement in the mass from the considerable noise in the inclinometer data. The raw data along with the repeatability tests and filtered results are available in the data files on the accompanying floppy disks. The horizontal and vertical displacements measured in each hole from the filtered data is plotted in Figures 4-59 to 4-77.

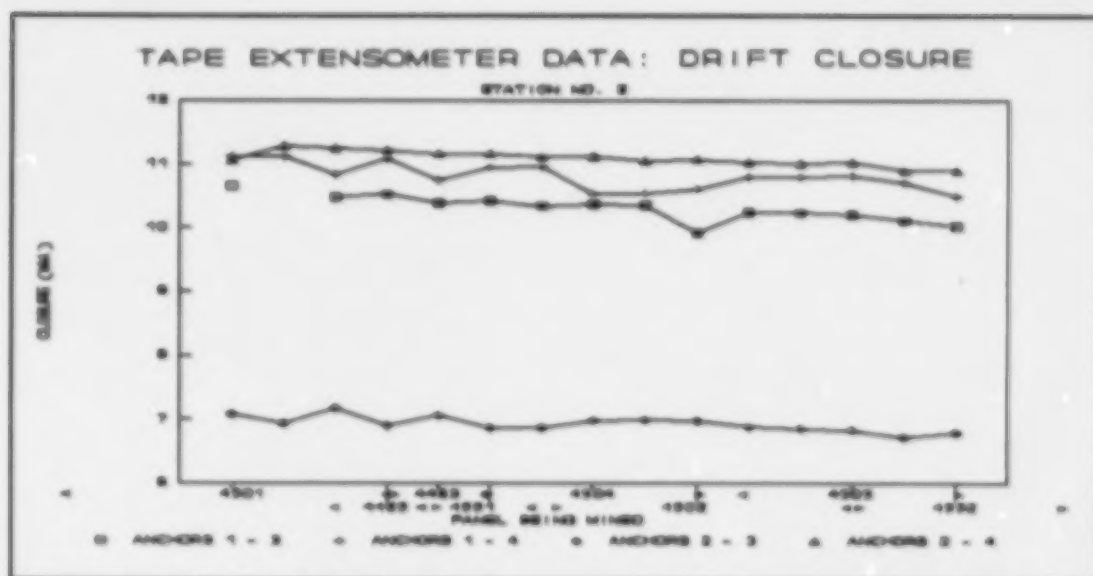


Figure 4-24 6600 Level Station 2 Tape Extensometer Data

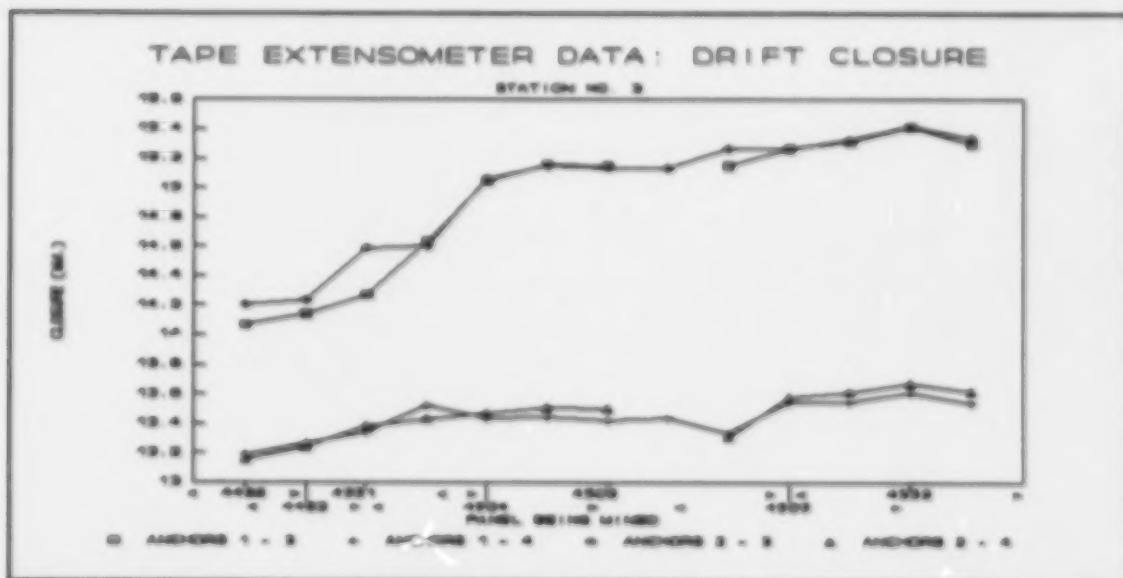


Figure 4-25 6600 Level Station 3 Tape Extensometer Data

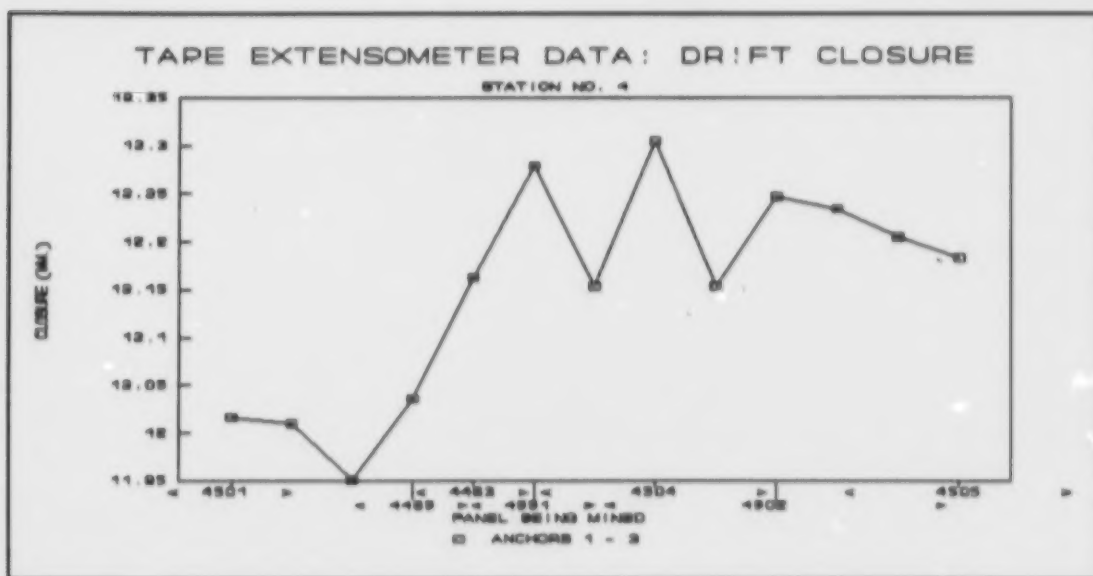


Figure 4-26 6600 Level Station 4 Tape Extensometer Data

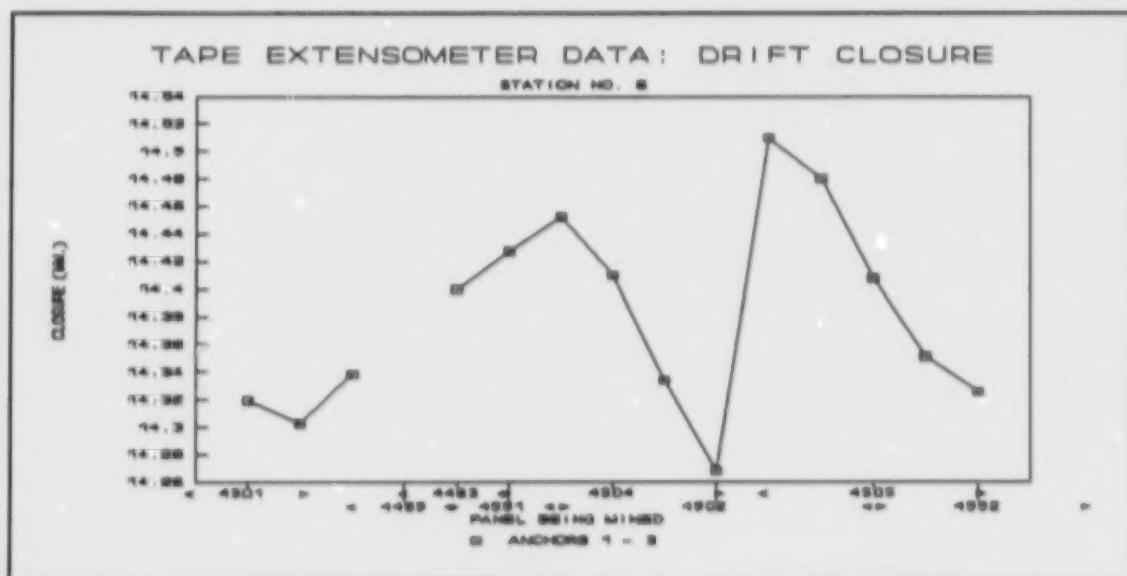


Figure 4-27 6600 Level Station 6 Tape Extensometer Data

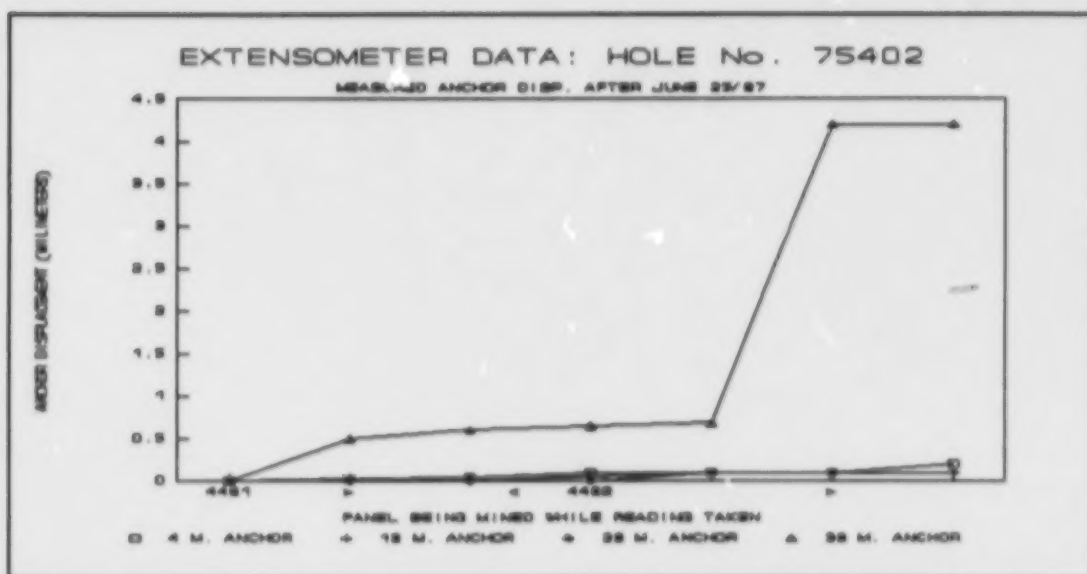


Figure 4-28 Extensometer Displacement Data - Hole 75402

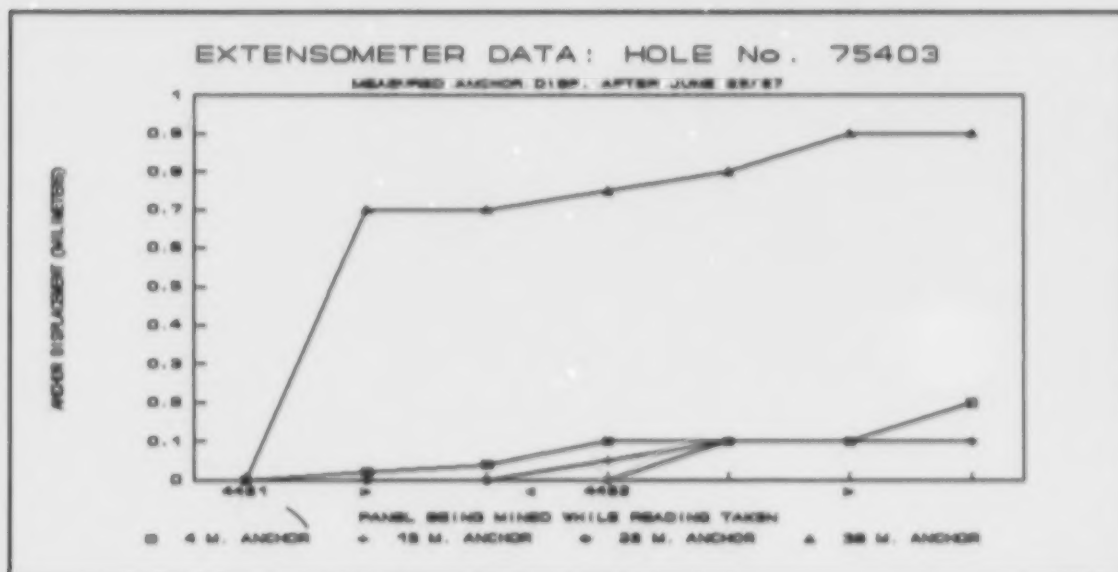


Figure 4-29 Extensometer Displacement Data - Hole 75403

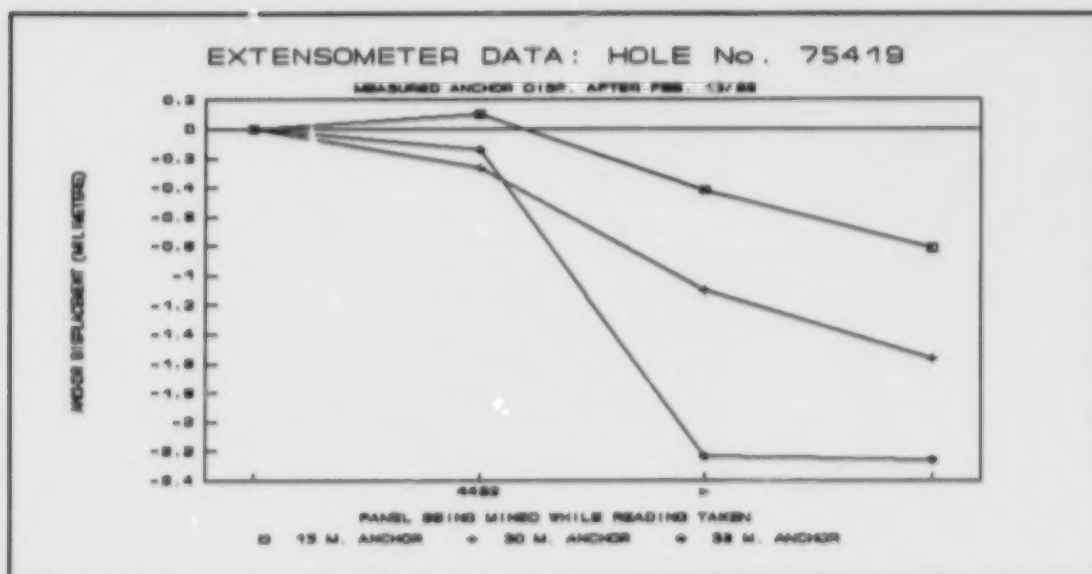


Figure 4-30 Extensometer Displacement Data - Hole 75419

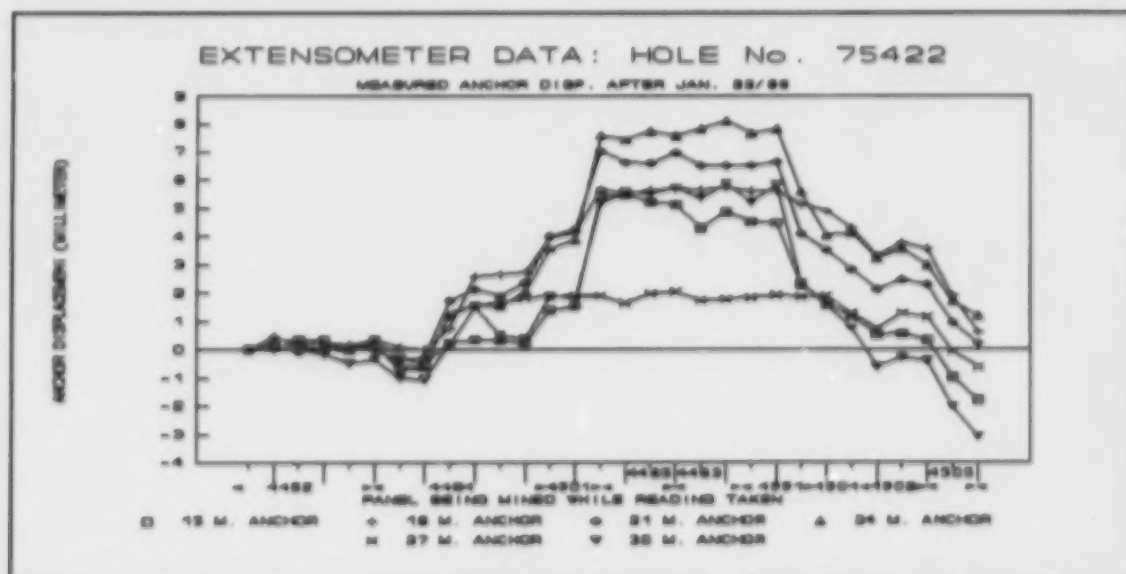


Figure 4-31 Extensometer Displacement Data - Hole 75422

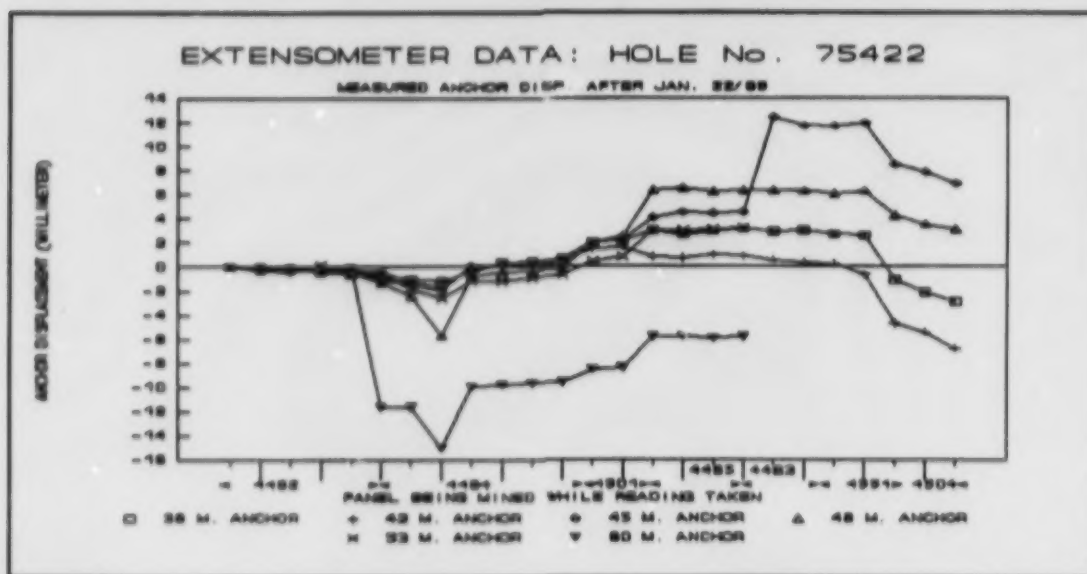


Figure 4-32 Extensometer Displacement Data - Hole 75422

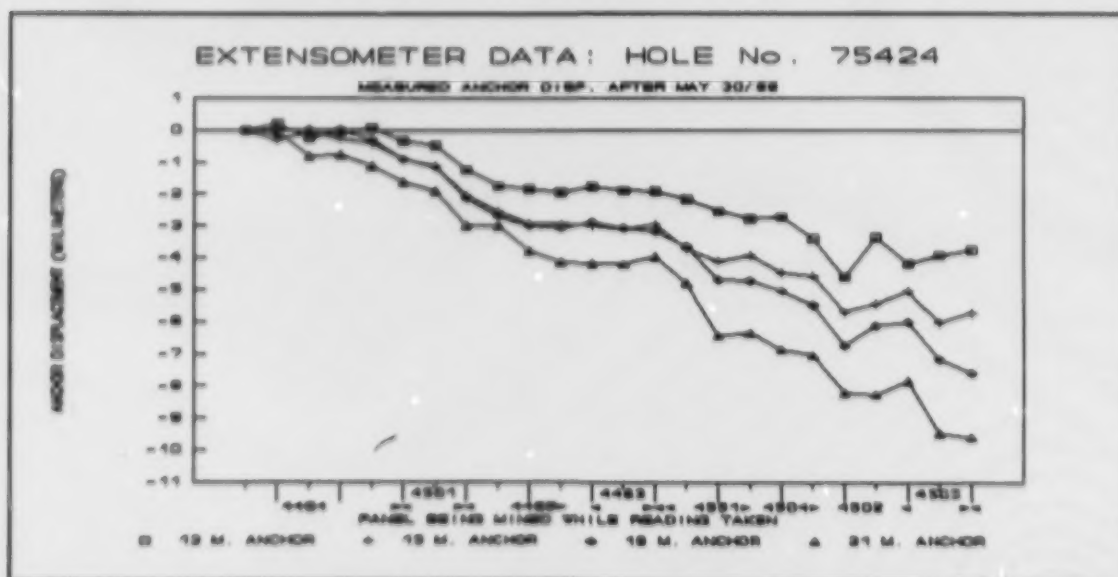


Figure 4-33 Extensometer Displacement Data - Hole 75424

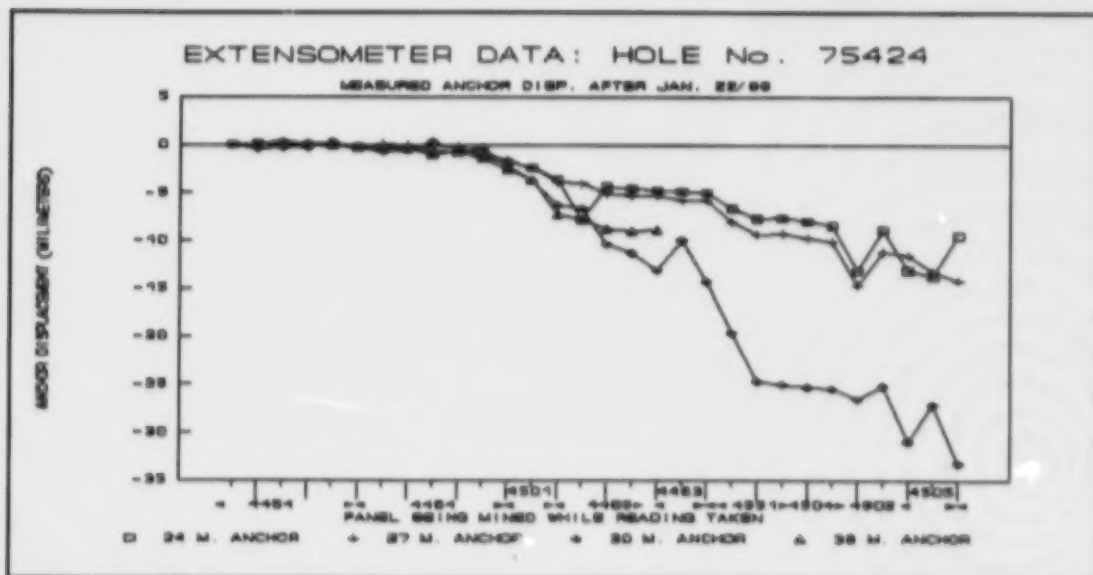


Figure 4-34 Extensometer Displacement Data - Hole 75424

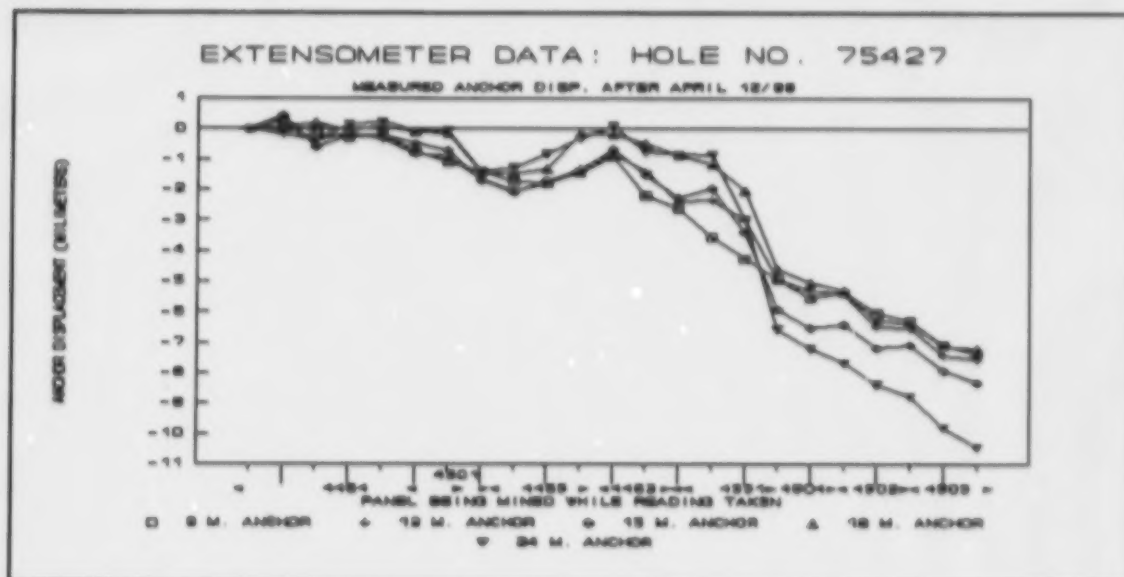


Figure 4-35 Extensometer Displacement Data - Hole 75427

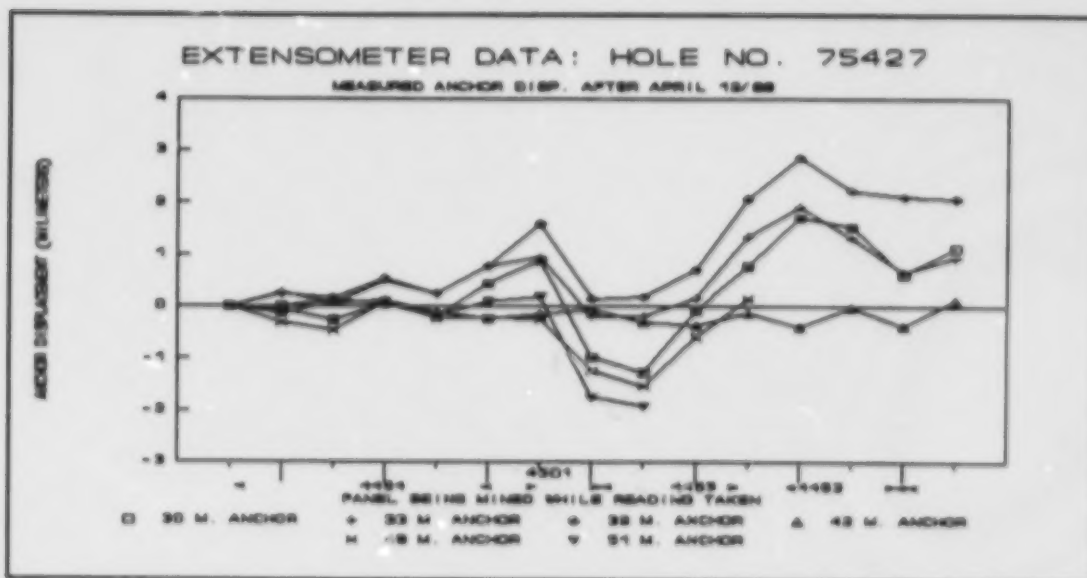


Figure 4-36 Extensometer Displacement Data - Hole 75427

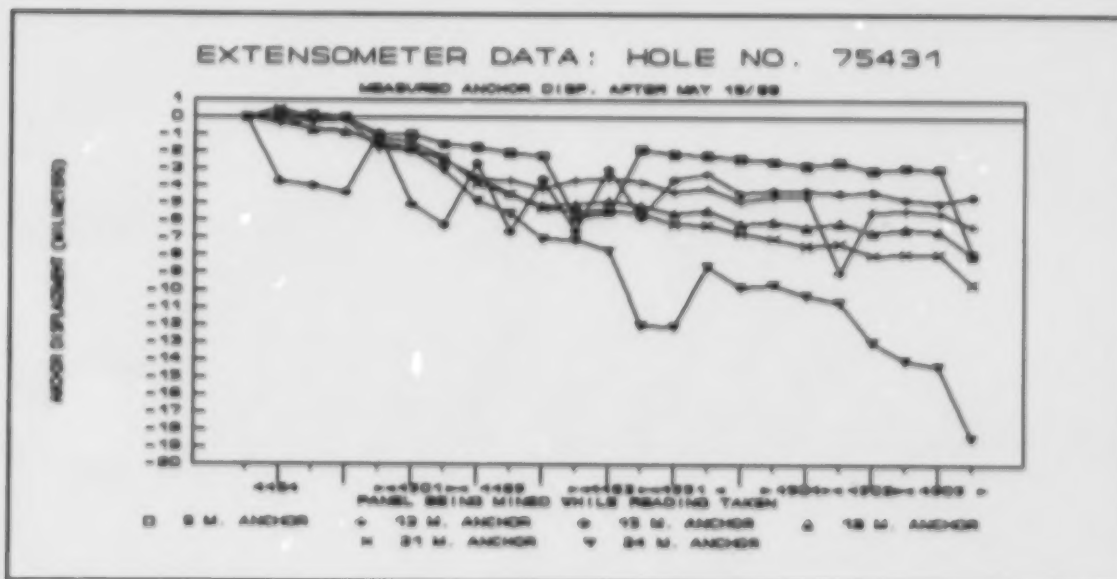


Figure 4-37 Extensometer Displacement Data - Hole 75431

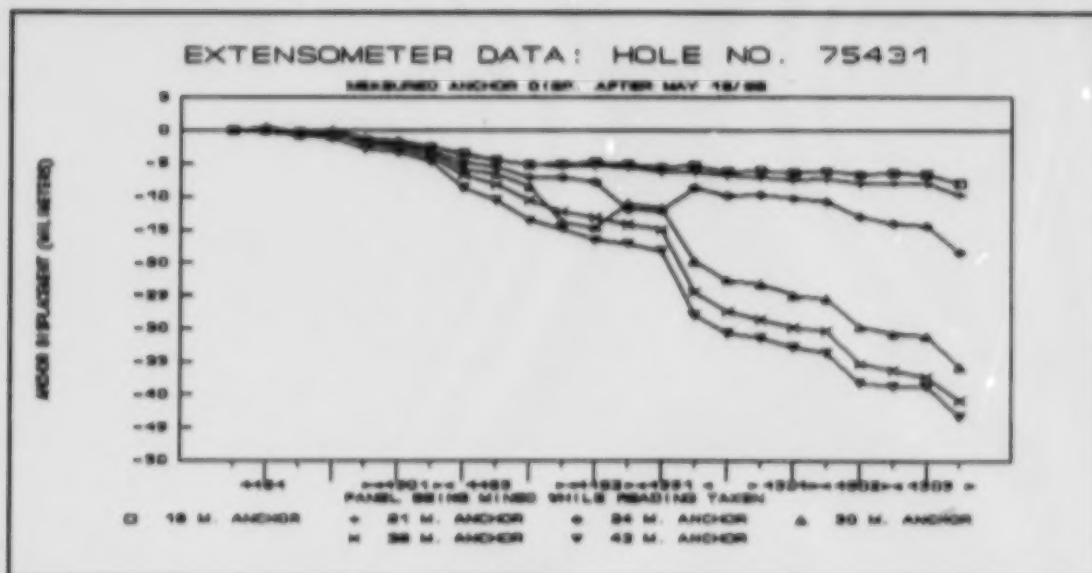


Figure 4-38 Extensometer Displacement Data - Hole 75431

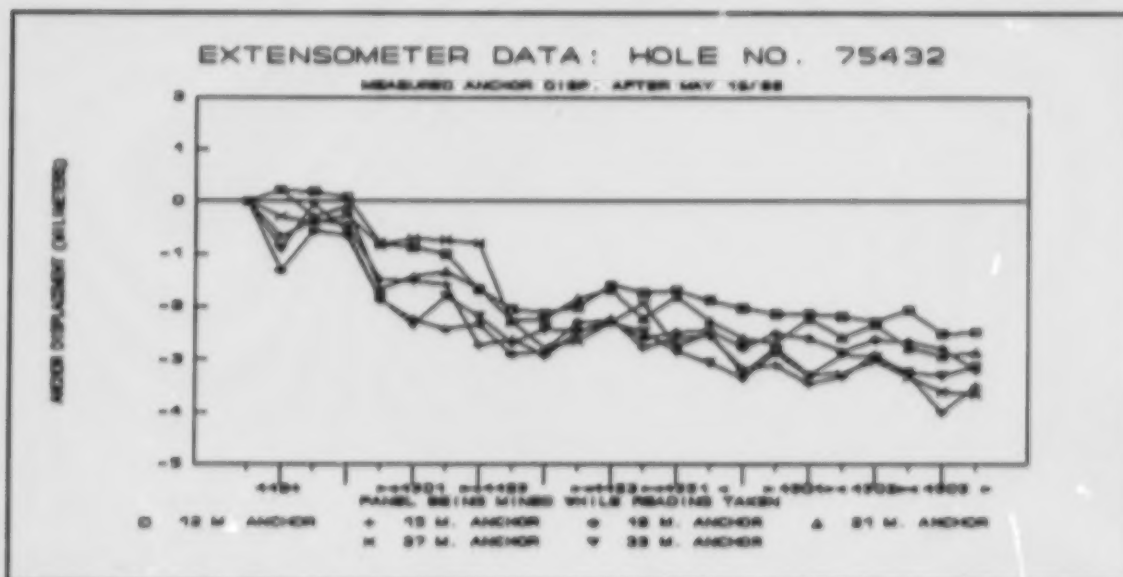


Figure 4-39 Extensometer Displacement Data - Hole 75432

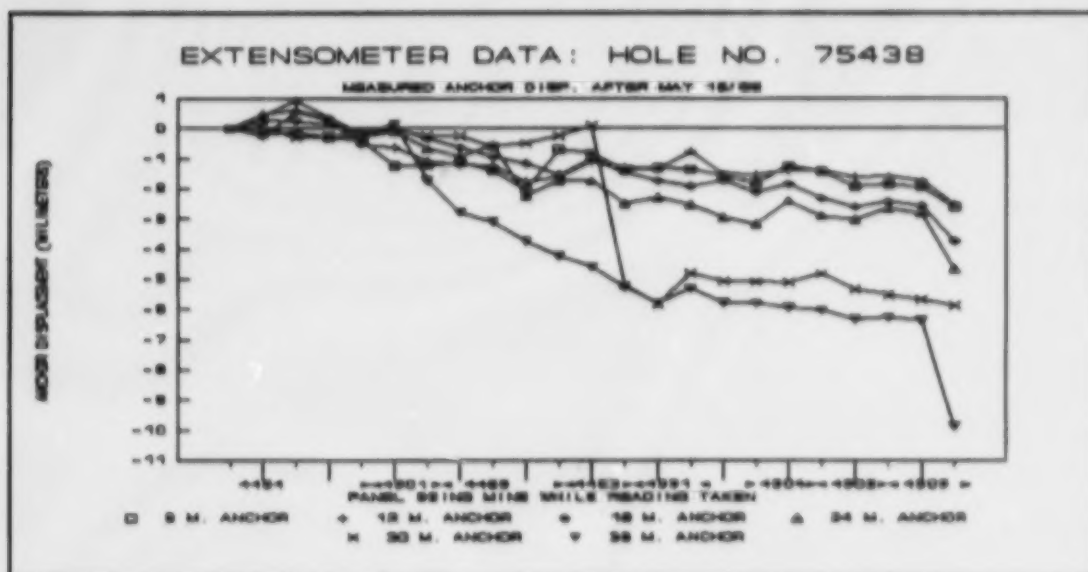


Figure 4-40 Extensometer Displacement Data - Hole 75438

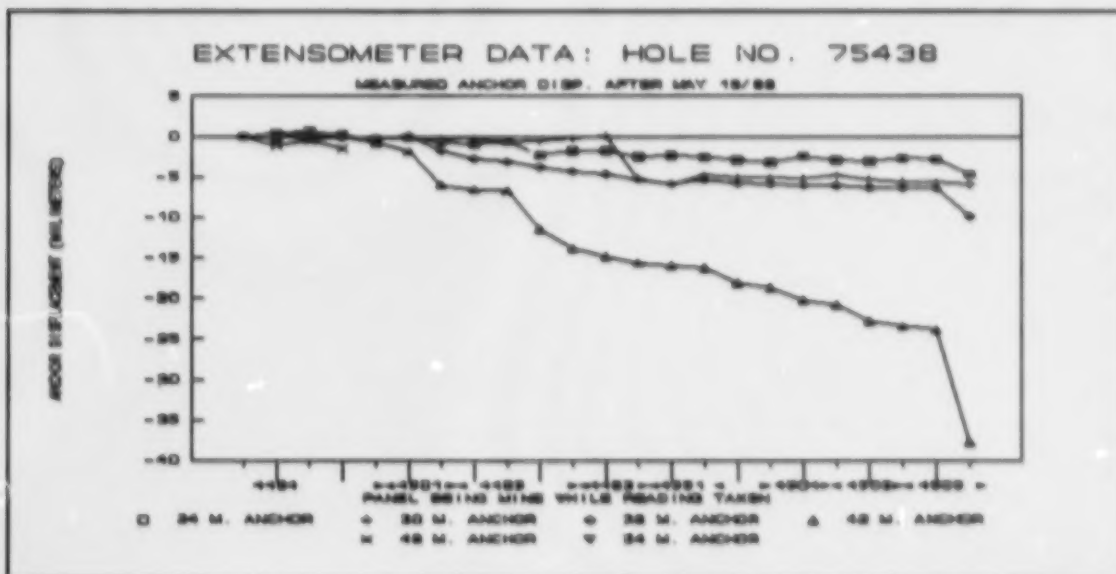


Figure 4-41 Extensometer Displacement Data - Hole 75438

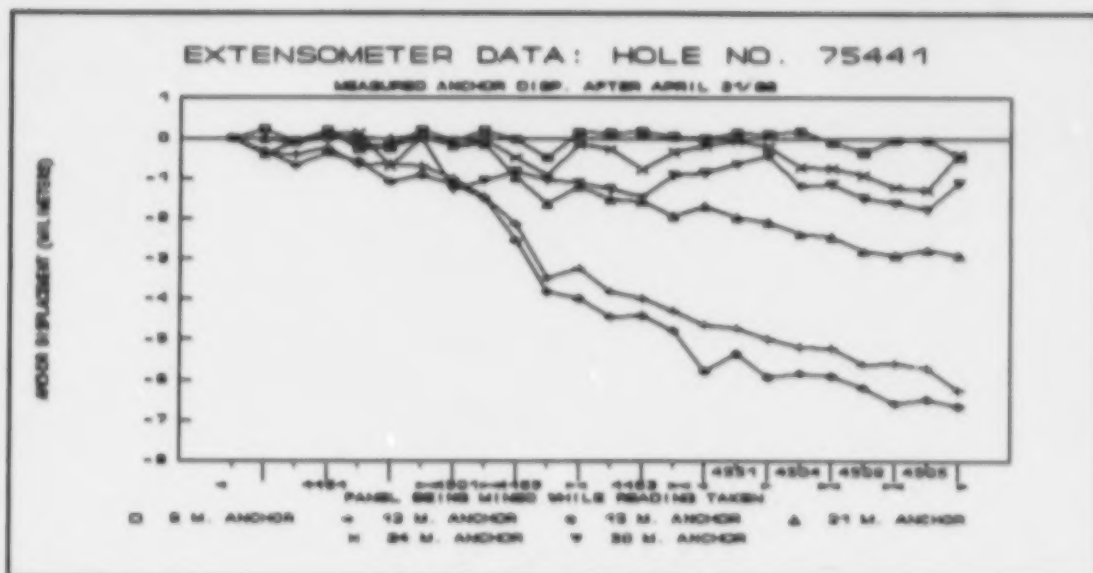


Figure 4-42 Extensometer Displacement Data - Hole 75441

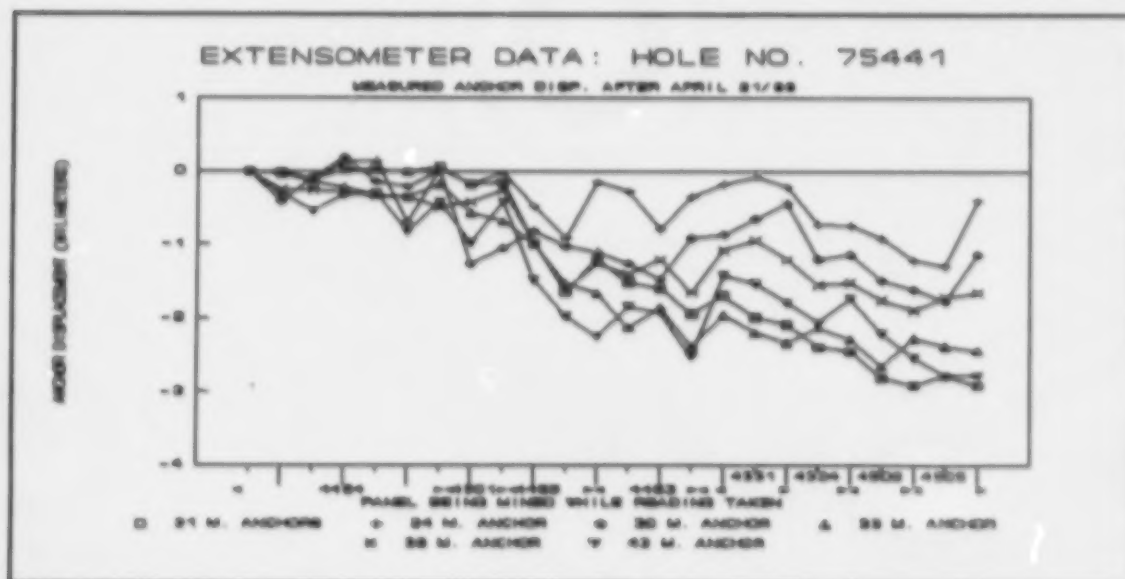


Figure 4-43 Extensometer Displacement Data - Hole 75441

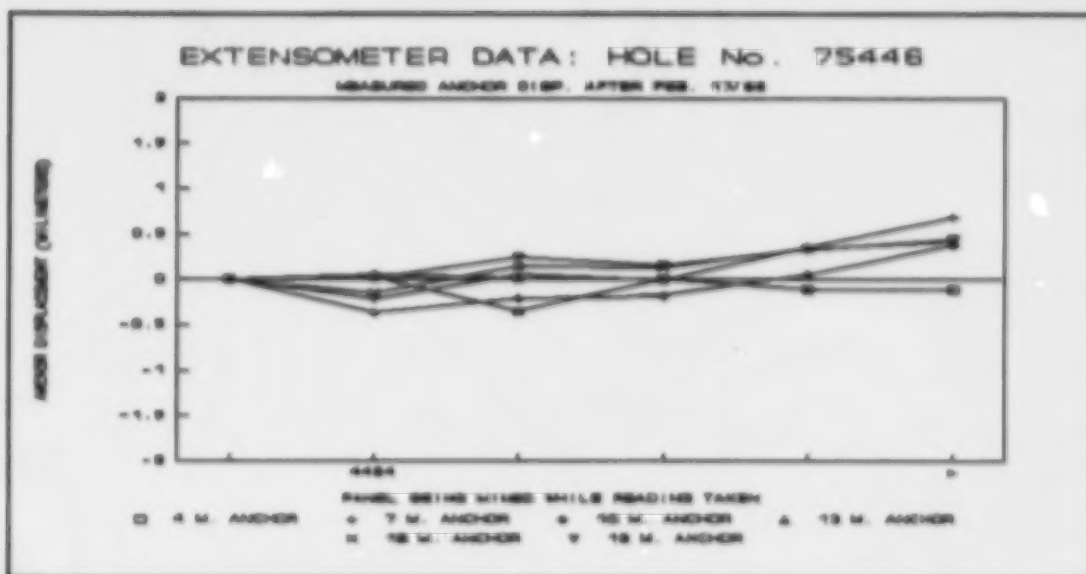


Figure 4-44 Extensometer Displacement Data - Hole 75446

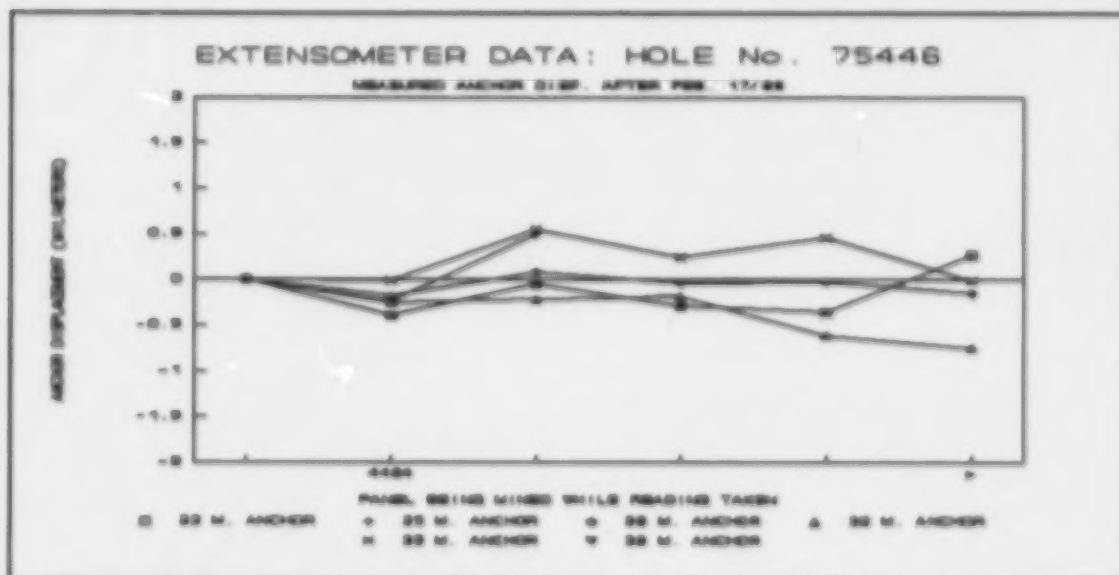


Figure 4-45 Extensometer Displacement Data - Hole 75446

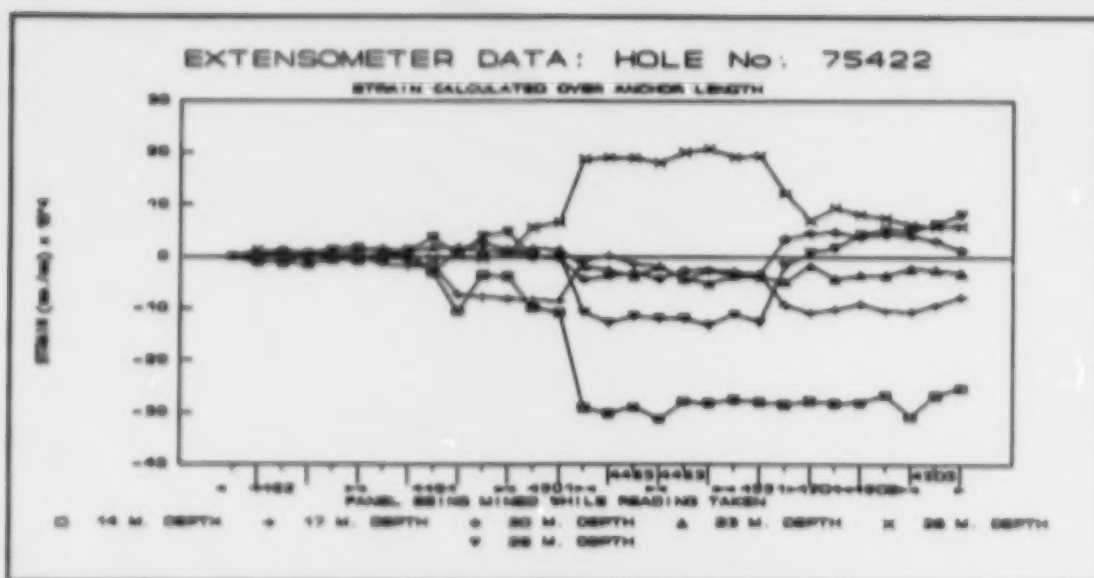


Figure 4-46 Strain Between Extensometer Anchors - Hole 75422

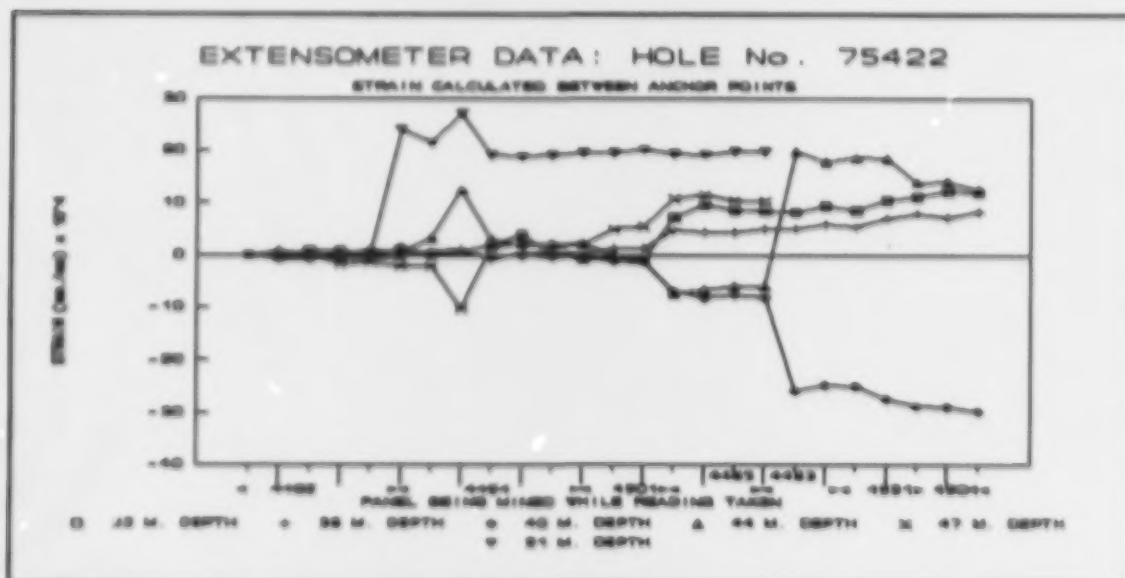


Figure 4-47 Strain Between Extensometer Anchors - Hole 75422

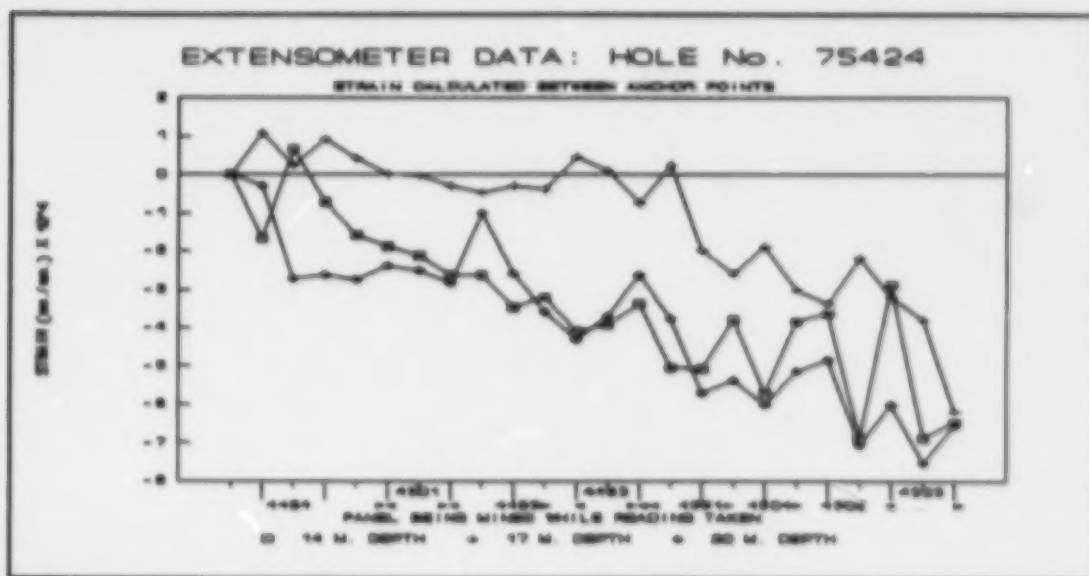


Figure 4-48 Strain Between Extensometer Anchors - Hole 75424

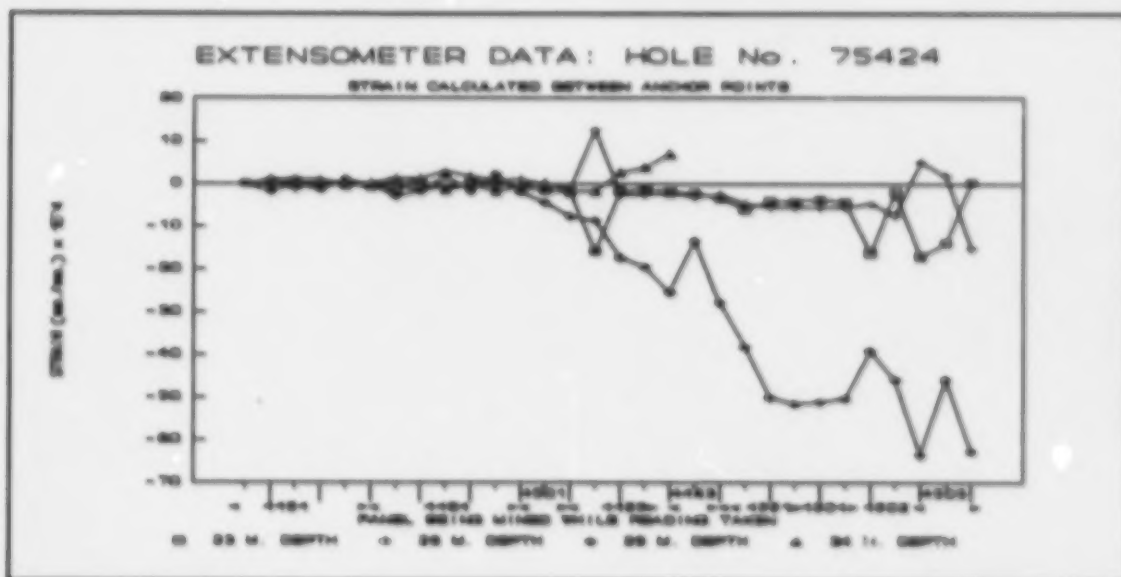


Figure 4-49 Strain Between Extensometer Anchors - Hole 75424

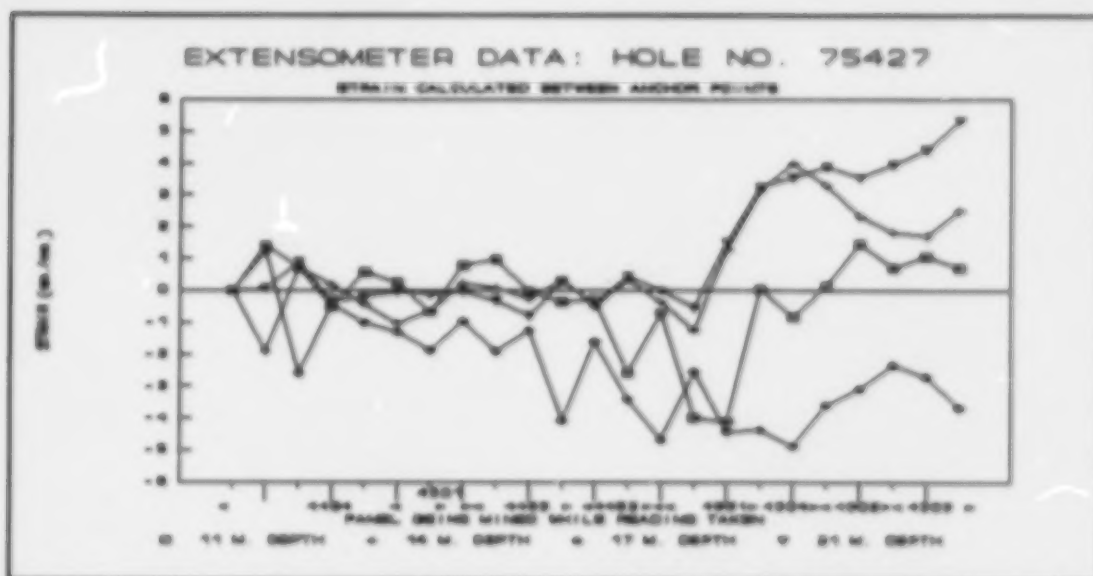


Figure 4-50 Strain Between Extensometer Anchors - Hole 75427

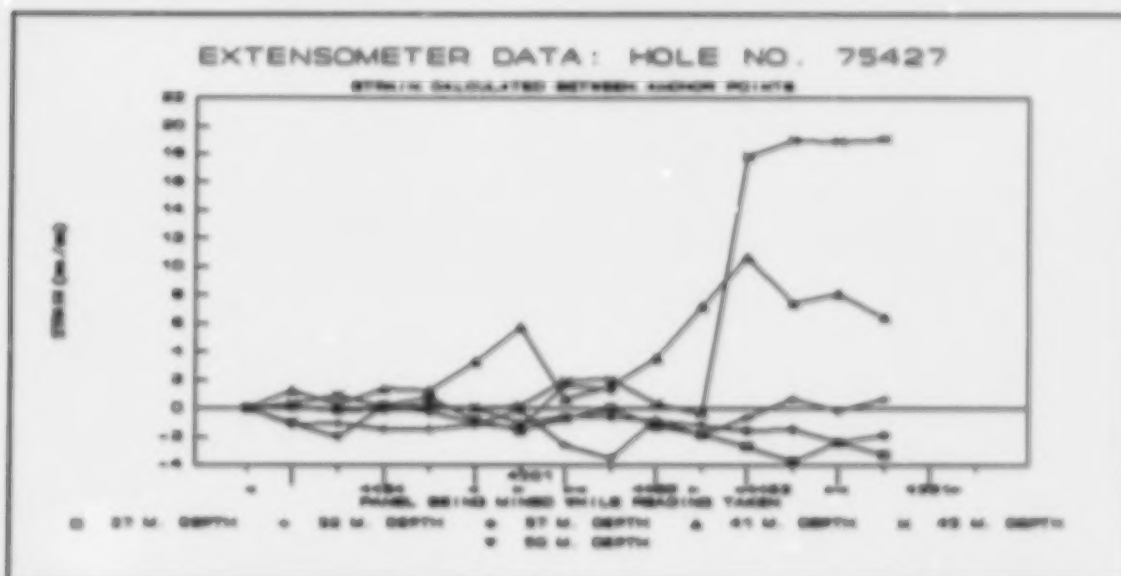


Figure 4-51 Strain Between Extensometer Anchors - Hole 75427

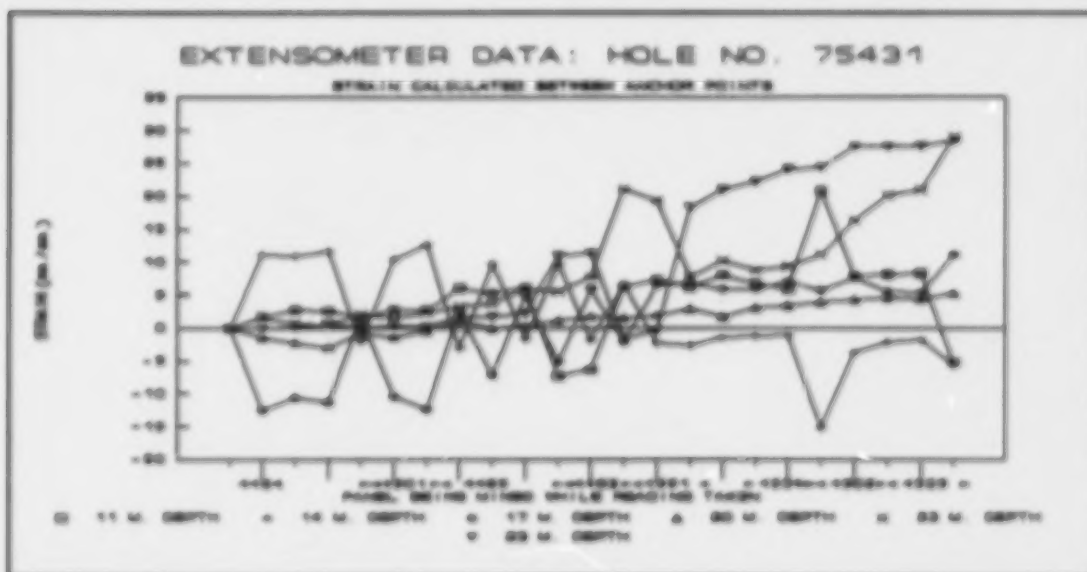


Figure 4-52 Strain Between Extensometer Anchors - Hole 75431

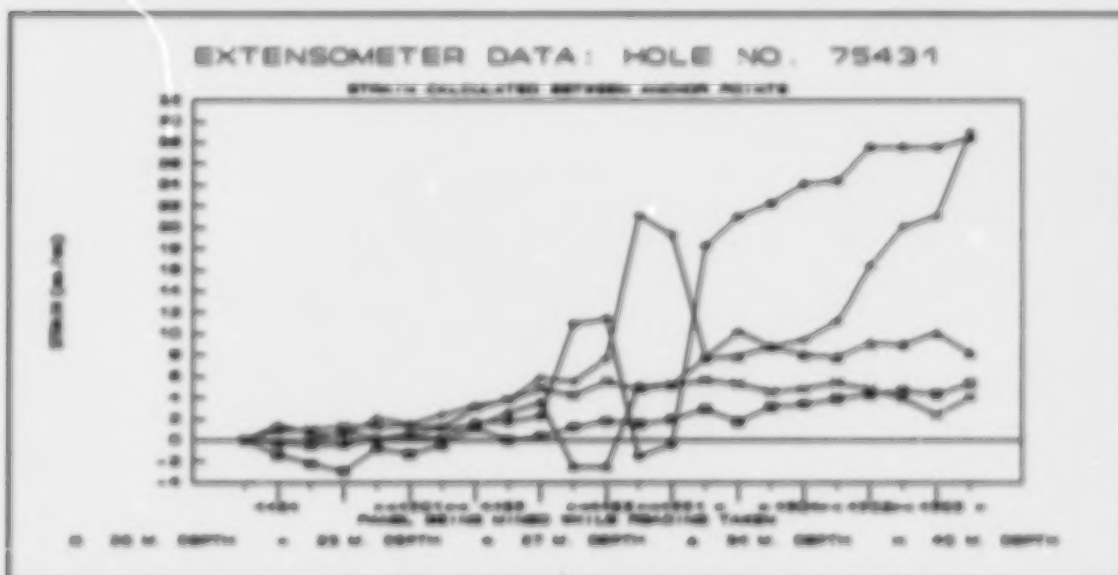


Figure 4-53 Strain Between Extensometer Anchors - Hole 75431

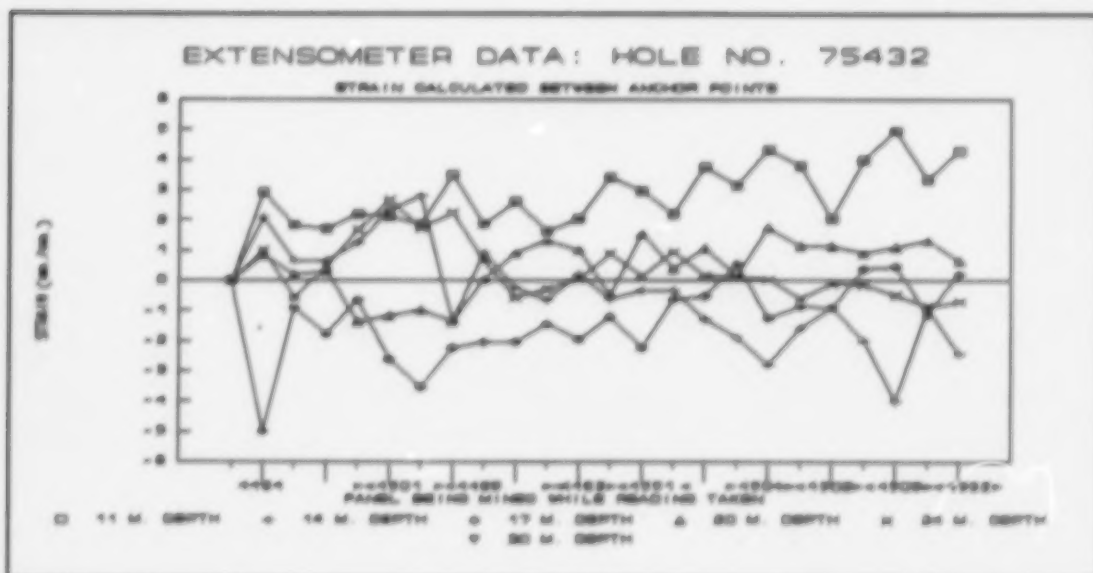


Figure 4-54 Strain Between Extensometer Anchors - Hole 75432

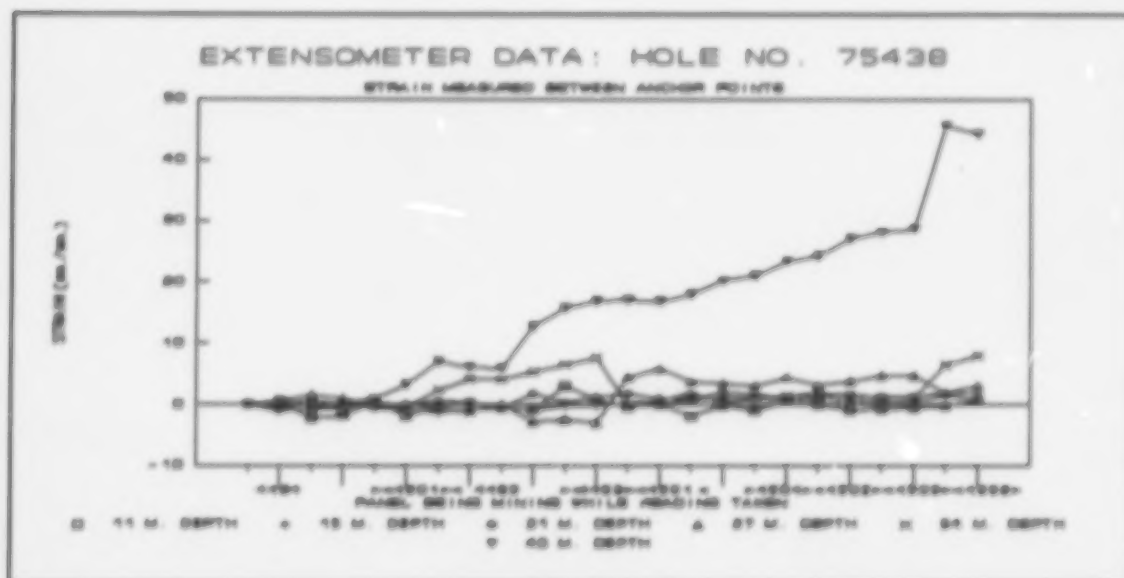


Figure 4-55 Strain Between Extensometer Anchors - Hole 75438

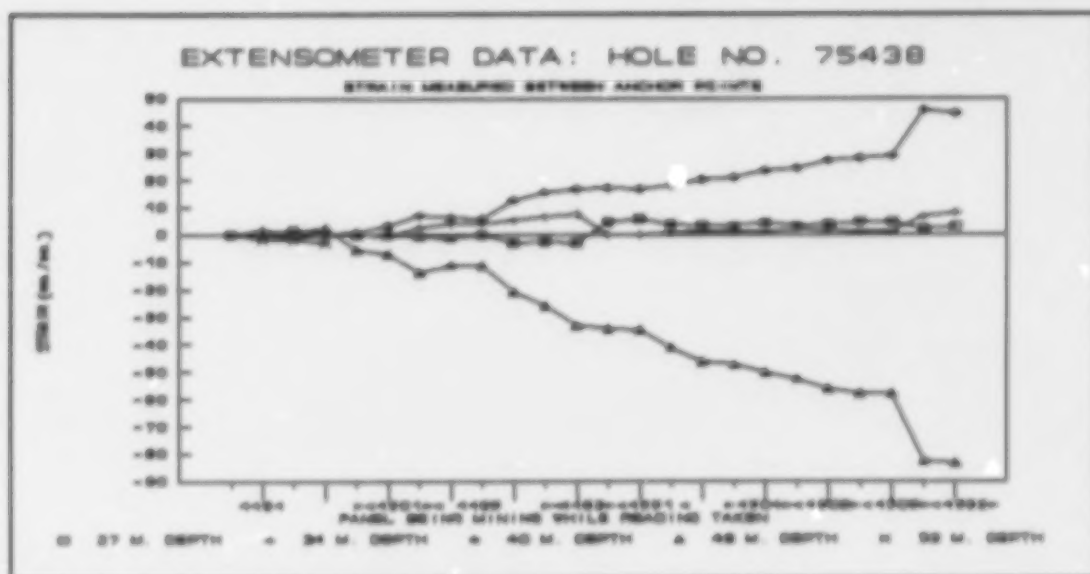


Figure 4-56 Strain Between Extensometer Anchors - Hole 75438

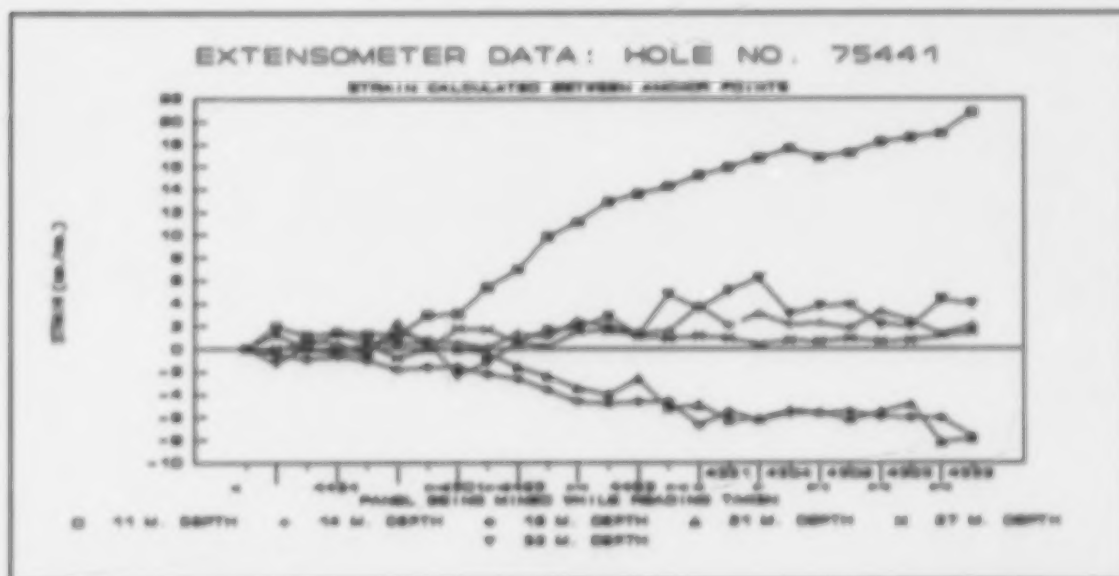


Figure 4-57 Strain Between Extensometer Anchors - Hole 75441

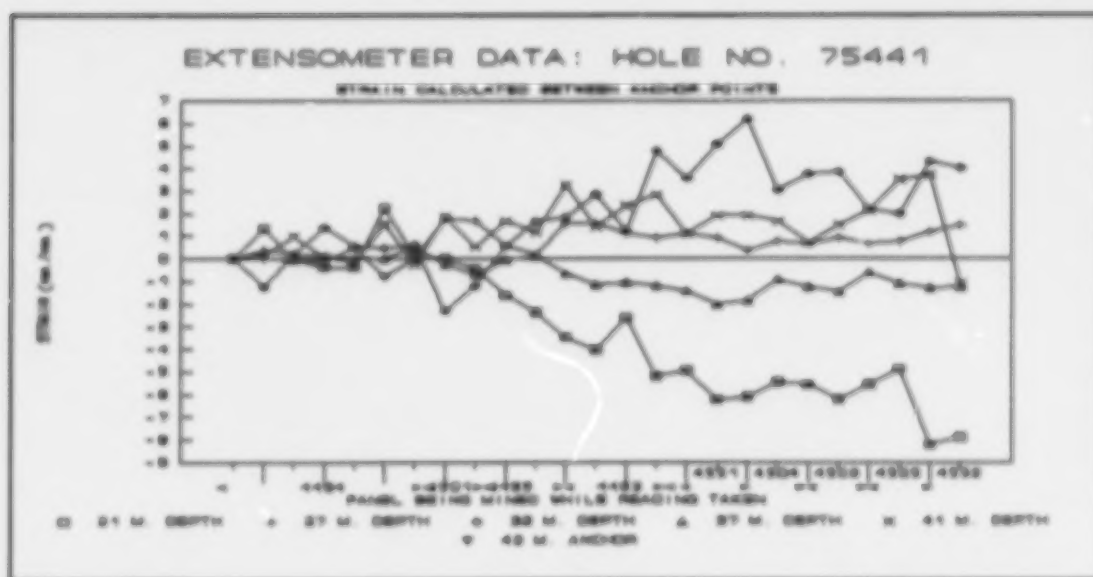


Figure 4-58 Strain Between Extensometer Anchors - Hole 75441

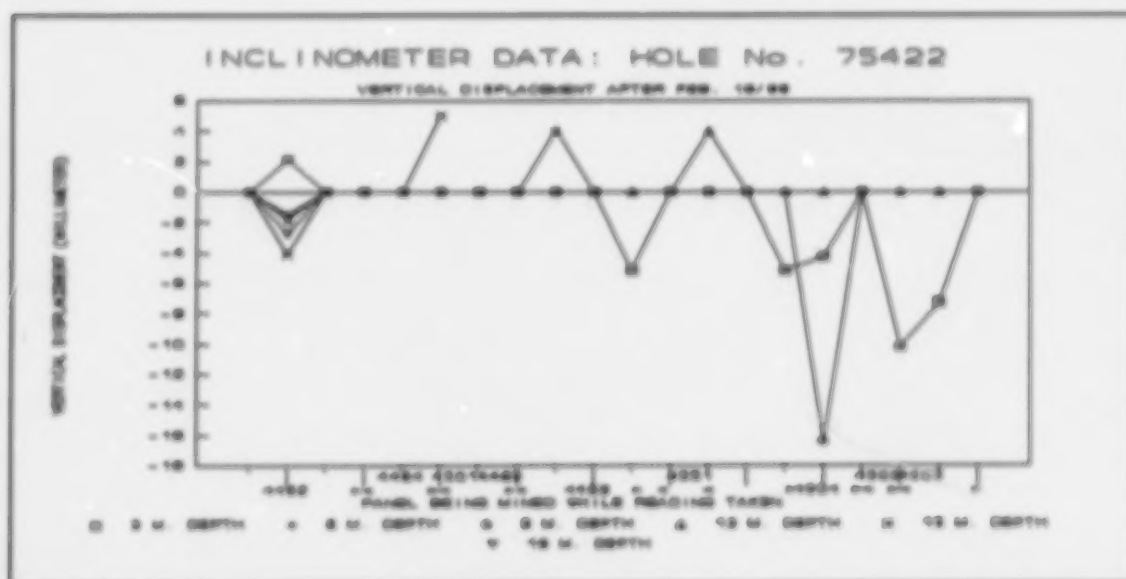


Figure 4-59 Inclinometer Displacement Data - Hole 75422

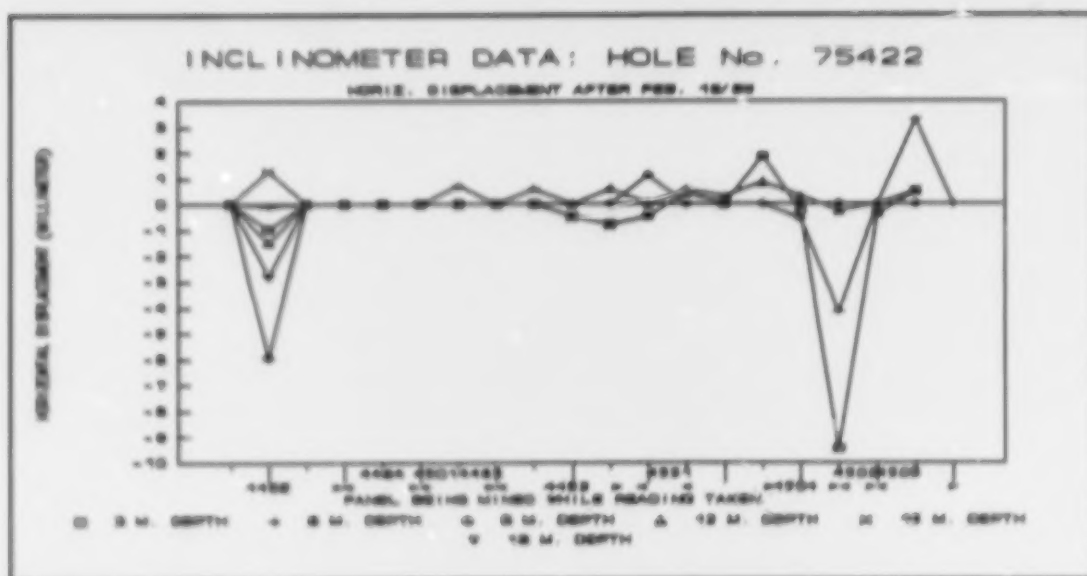


Figure 4-60 Inclinator Displacement Data - Hole 75422

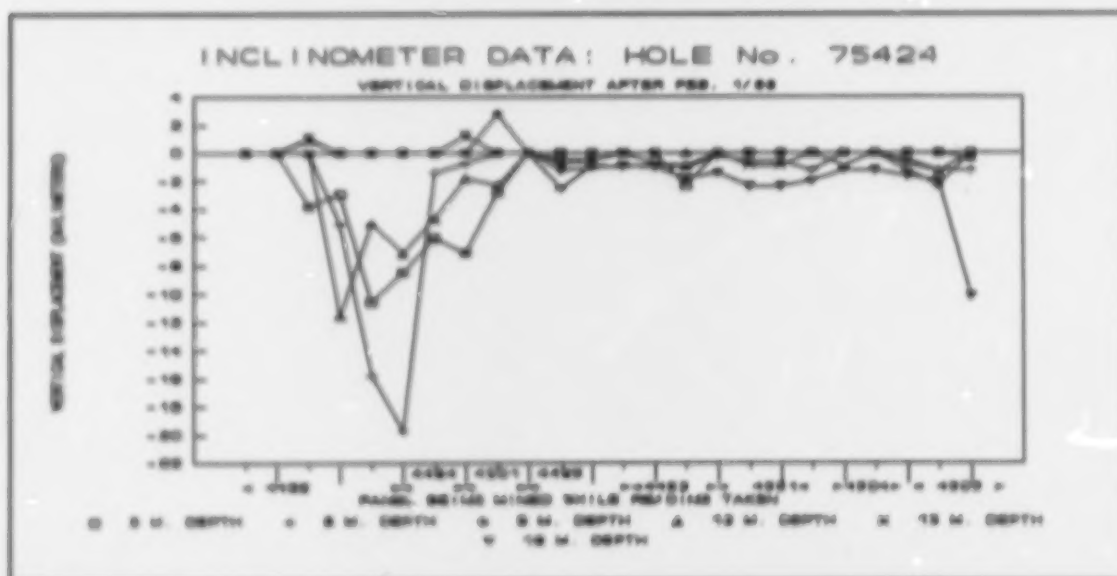


Figure 4-61 Inclinator Displacement Data - Hole 75424

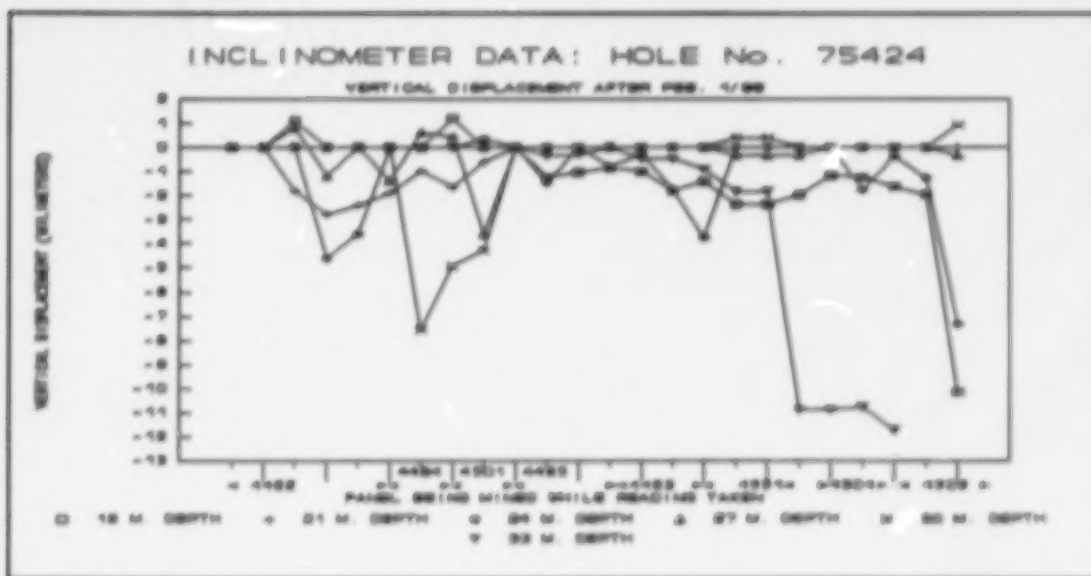


Figure 4-62 Inclinerometer Displacement Data - Hole 75424

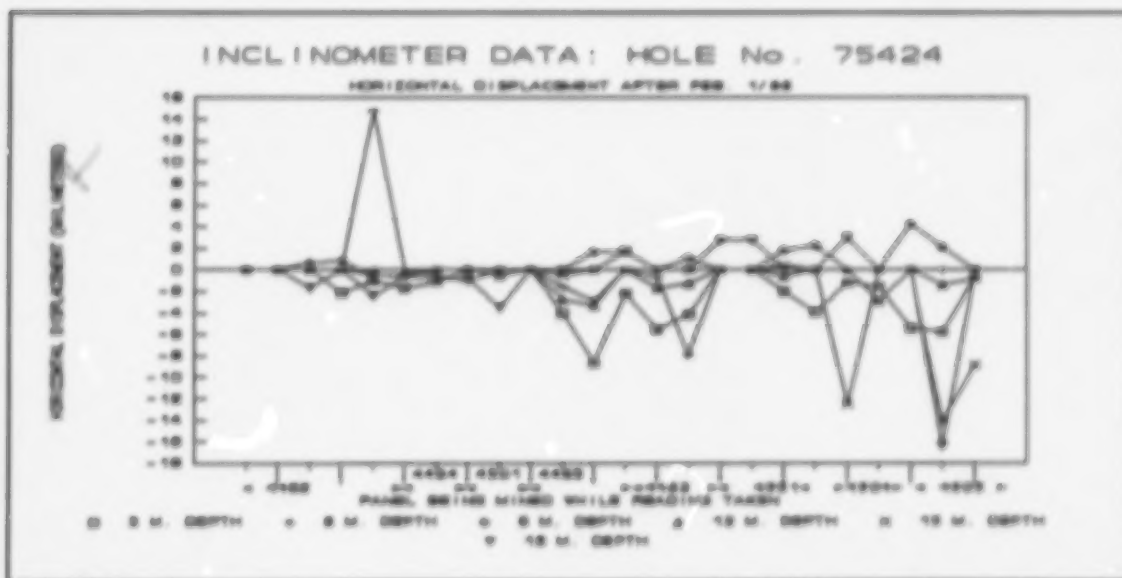


Figure 4-62 Inclinerometer Displacement Data - Hole 75424

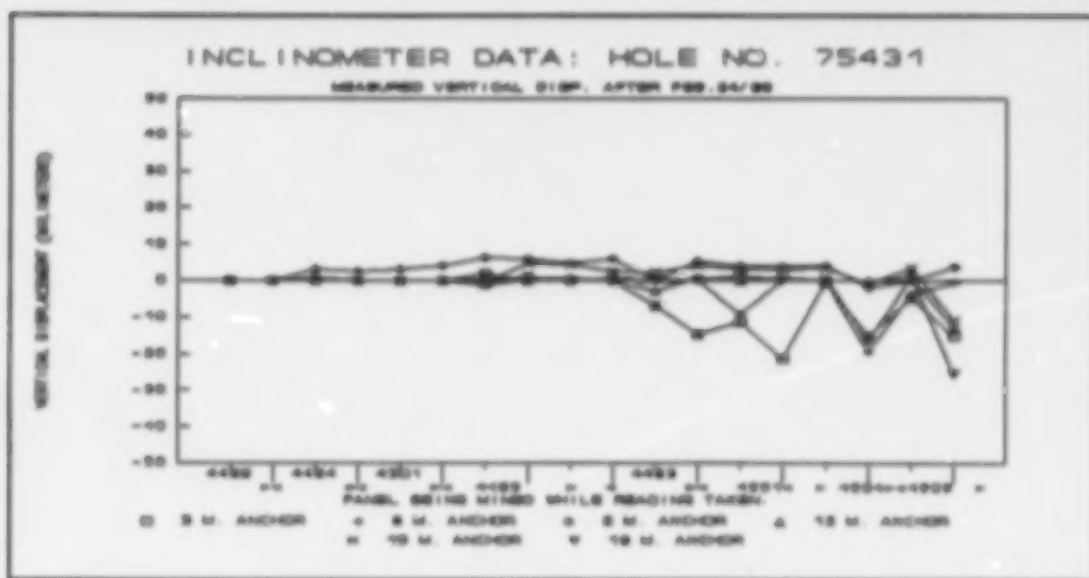


Figure 4-64 Inclinator Displacement Data - Hole 75431

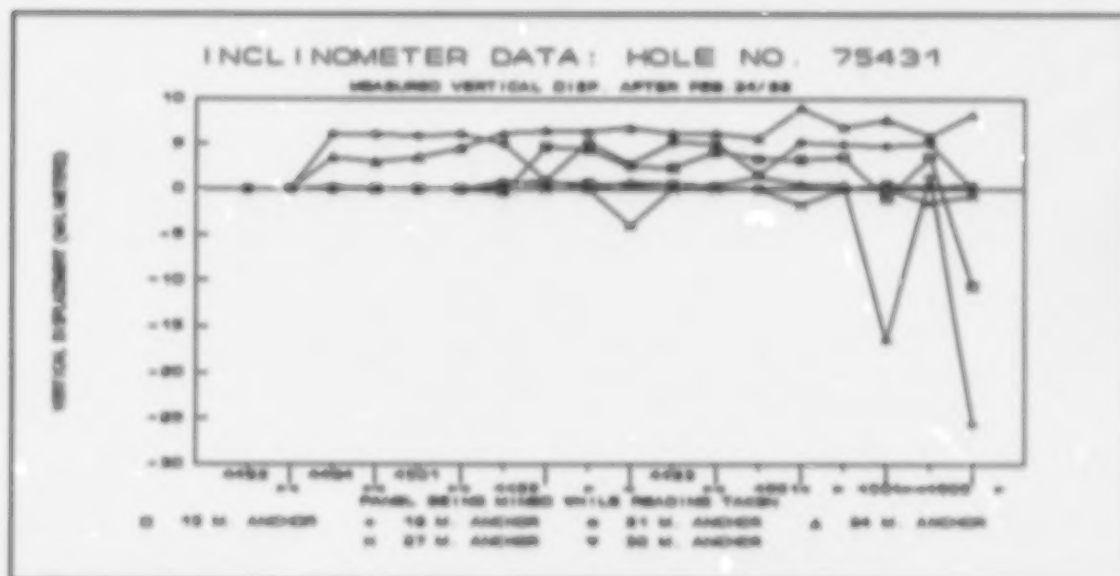


Figure 4-65 Inclinator Displacement Data - Hole 75431

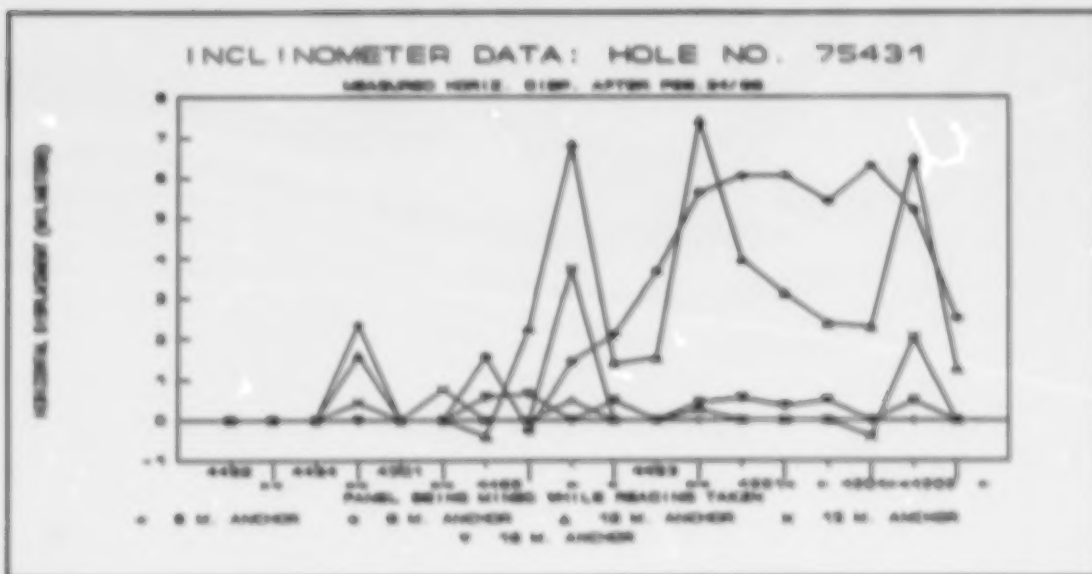


Figure 4-66 Inclinator Displacement Data - Hole 75431

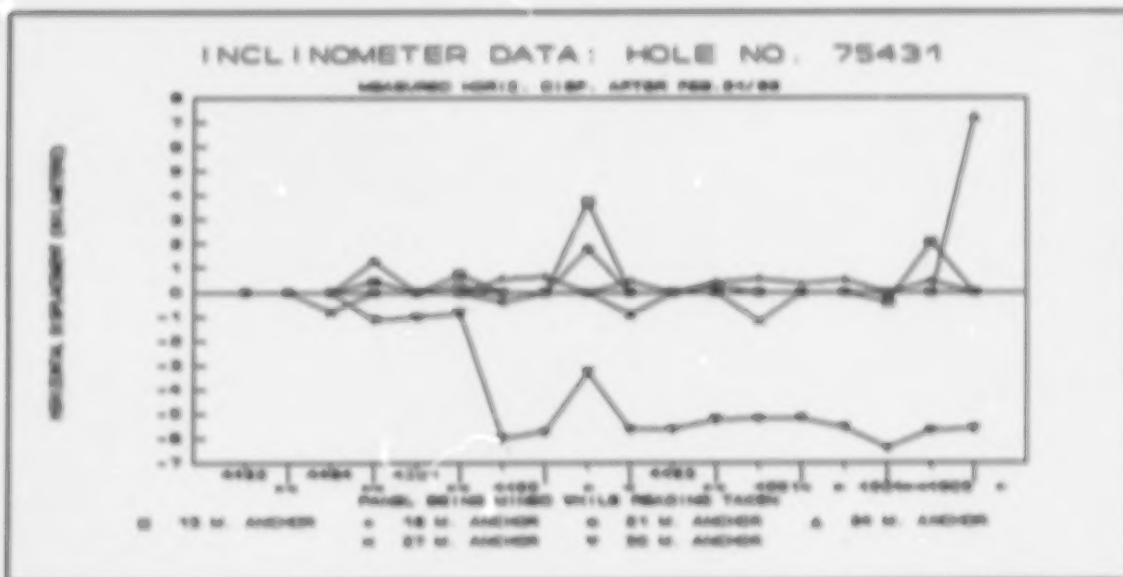


Figure 4-67 Inclinator Displacement Data - Hole 75431

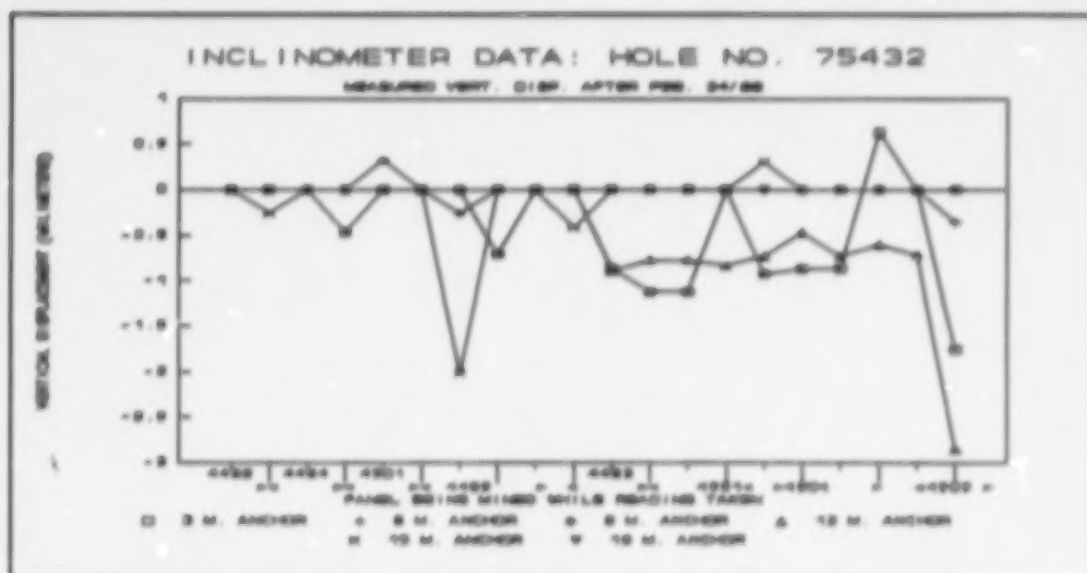


Figure 4-68 Incliner Displacement Data - Hole 75432

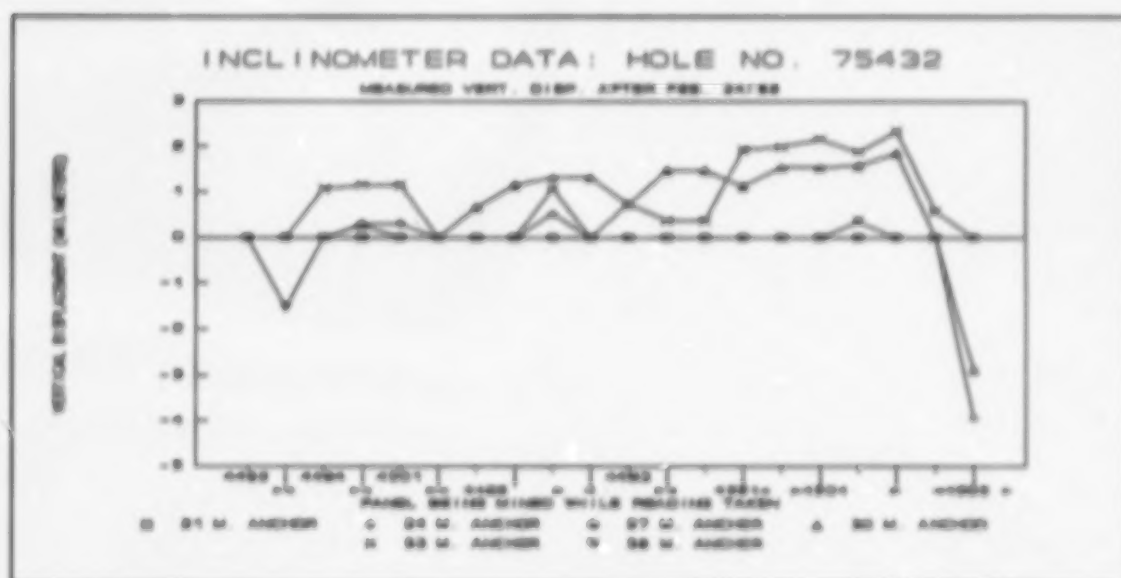


Figure 4-69 Incliner Displacement Data - Hole 75432

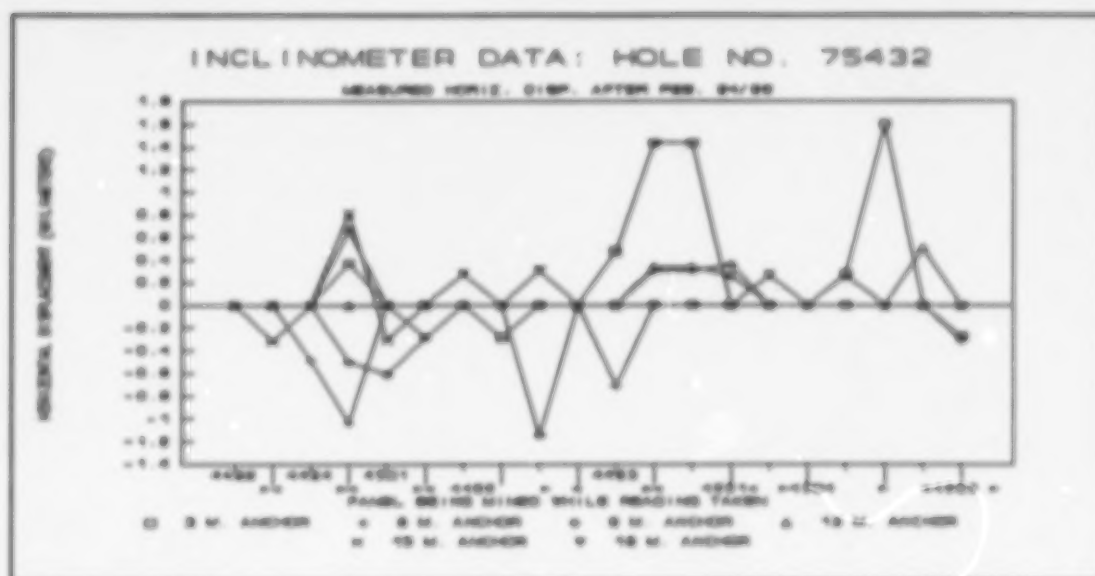


Figure 4-70 Inclinator Displacement Data - Hole 75432

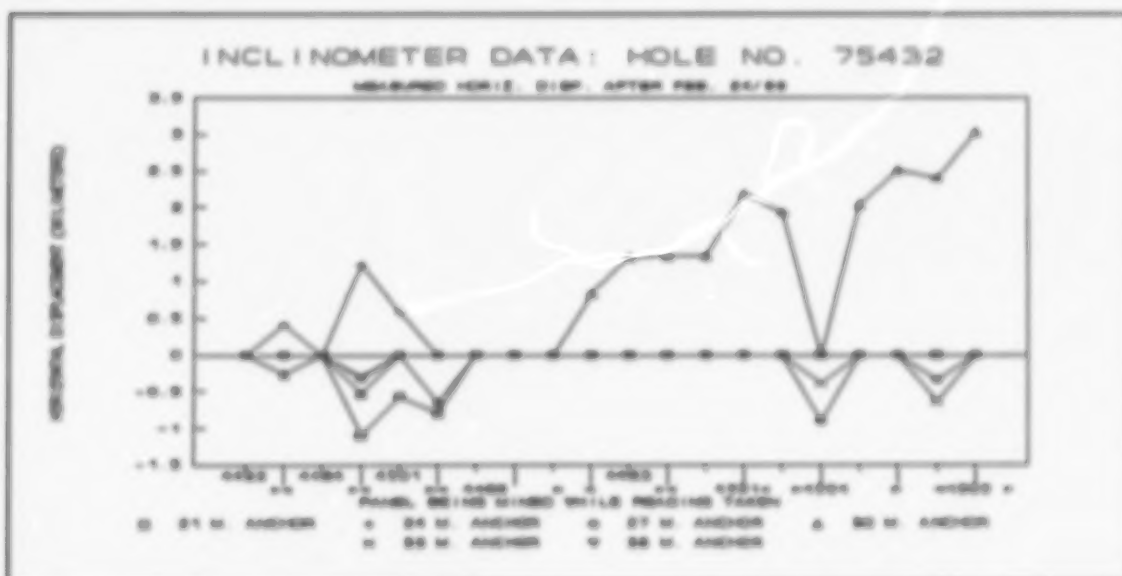


Figure 4-71 Inclinator Displacement Data - Hole 75432

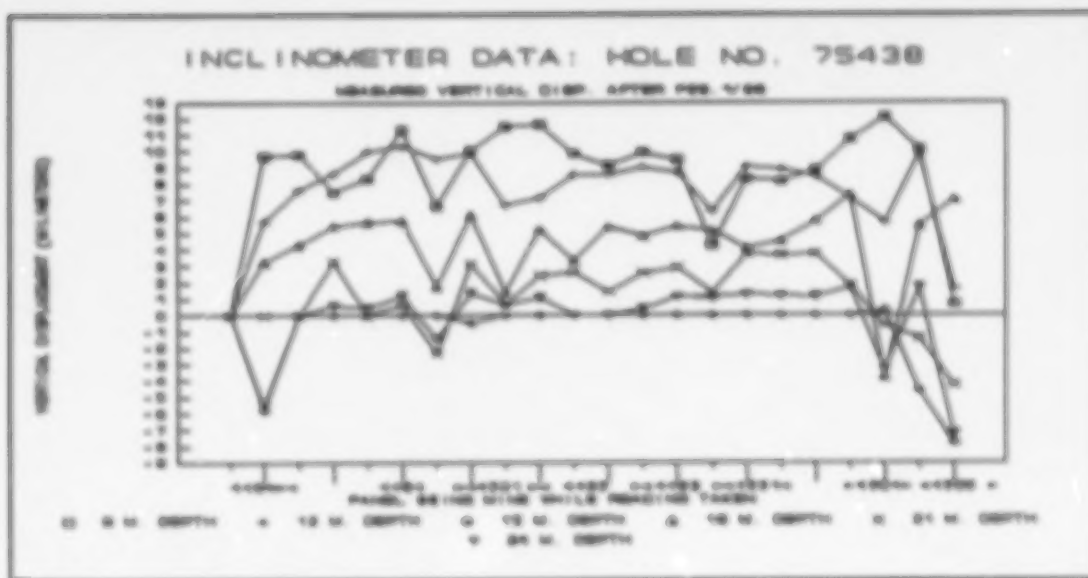


Figure 4-72 Inclinator Displacement Data - Hole 75438

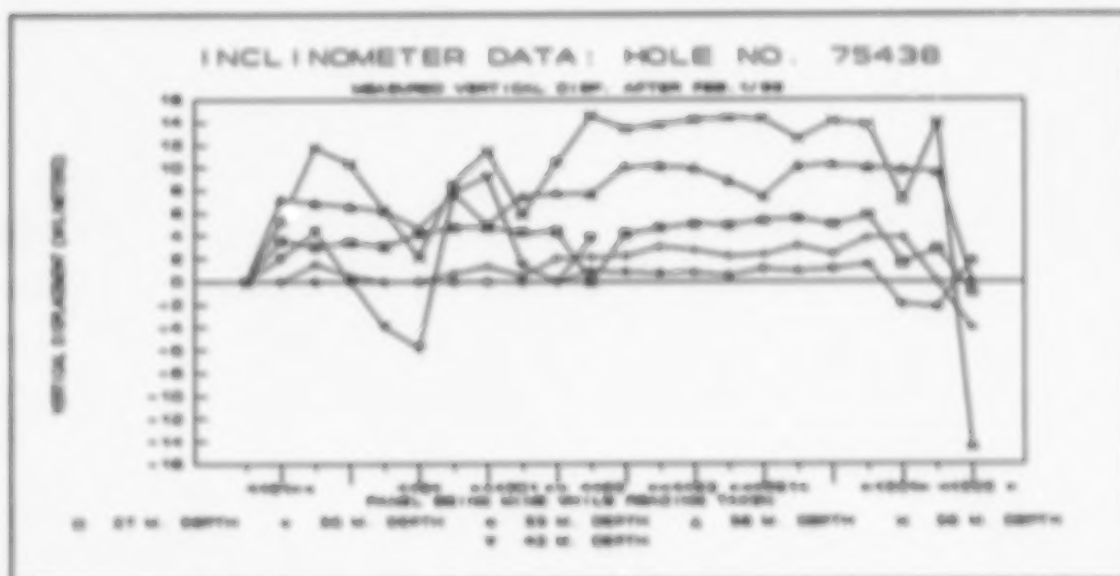


Figure 4-73 Inclinator Displacement Data - Hole 75438

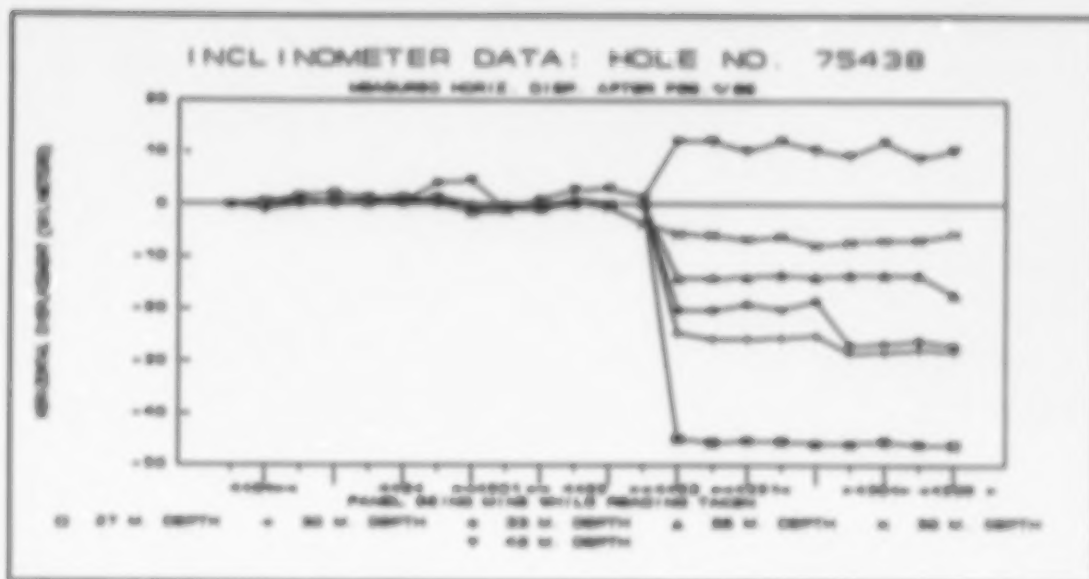


Figure 4-76 Inclinator Displacement Data - Hole 75438

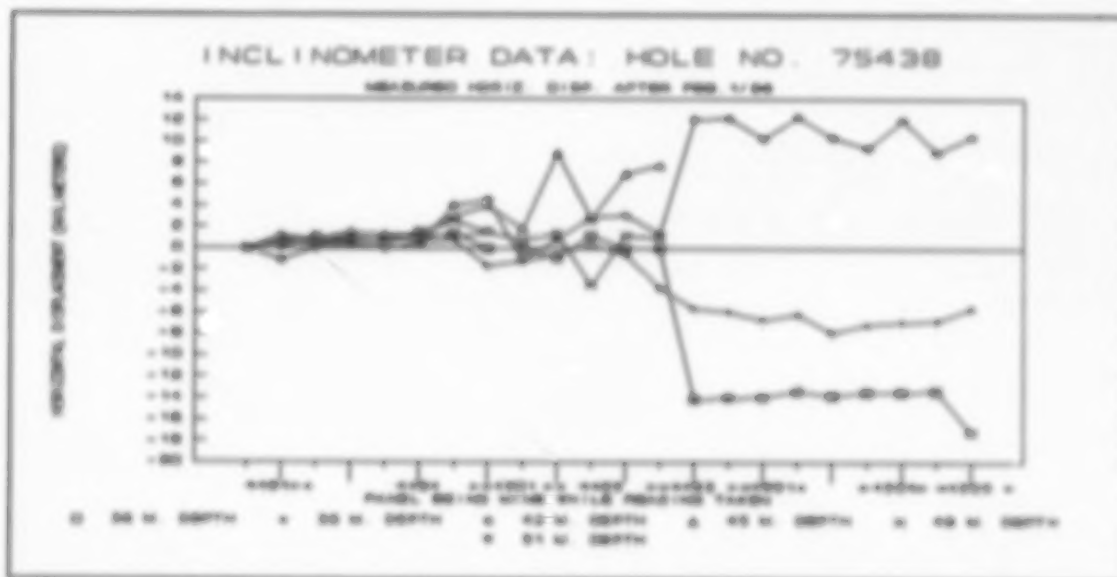


Figure 4-77 Inclinator Displacement Data - Hole 75438

The sign convention used is that positive displacement in the vertical plane, while looking down the hole axis, is to the top of the hole while negative displacement is to the bottom of the hole. Positive displacement in the horizontal plane of the hole axis is towards the right when looking down the hole from the collar. Negative displacement is to the left.

4.2.4.6 Theodolite Survey

The extensive array of displacement measurement equipment described above is designed specifically to determine movement inside the block. If 4500 block was to undergo some form of mass movement (i.e. mass vertical movement between the hangingwall and footwall) the internal displacement instrumentation may not indicate it. For this reason an attempt was made to periodically survey the entire block on 6600 and 6700 levels using a TOPCON GTS-1B theodolite.

The survey was carried into the block from a station remote from the mining area to allow any major movement of the research sites to be detected. Unfortunately, the inaccuracy of the survey proved to be so great that it made the exercise useless and it was abandoned early in the project.

4.2.5 Stress Change

4.2.5.1 Rock Mass Stress Change

The initial approach to determine the stress changes associated with the progressive mining in the monitoring site was to repeatedly install and overcore triaxial stress cells (C.S.I.R. and C.S.I.R.O. cells) at strategic locations throughout the monitoring site on both 6600 and 6700 levels. This approach, which continued for the first two years of the project, was eventually abandoned because of the low number of successful overcores. Over that two year period of overcoring a total of three stress measurements (Figure 4-78) were considered to be sufficiently reliable to use in the numerical code calibration.

The major problem encountered was finding ground sufficiently unstructured to warrant installing a cell for overcoring. When a suitable section of ground was located and the cell installed the installation was often unsuccessful due to the quick setting of the glue due to the high temperatures (40 deg. celsius) or the overcoring results were suspect because of partial de-bonding. The stresses determined from the overcoring strain data and the subsequent Hook cell tests data for the reliable overcores and several questionable attempts are given in the data files on floppy disk.

The overcoring of stress cells was replaced with a stress monitoring program in the third year of the project. A series of EX holes were drilled from 6700 level into the middle of 4500 VHM mining block. At the end of each a EX hole was drilled and a C.B.I.R.O. triaxial stress cell installed. Behind each triaxial cell, a biaxial Yoke cell was installed in the EX section of the hole to produce some redundancy in the monitoring data. These cells along with one cell installed on 6600 level were left in place to measure the strain changes that took place at these locations in the monitoring site as mining progressed.

The location of the successfully installed cells are shown in Figures 4-79, 4-80 and 4-81. The measured strain changes and calculated stresses are in the data files on floppy disks.

4.2.5.2 Backfill Stress Change

In an attempt to measure the biaxial stresses produced in the cemented backfill by the surrounding rock mass in 4500 block, earth pressure cells were buried in the tailings as specific panels were filled. The pressure cells were arranged on aluminum frames in a three cell rosette array to allow the biaxial stress tensor to be determined.

A total of 24 earth pressure cells were buried in backfill in six different V.R.M panels. Of these only four rosettes of cells were datalogged before the cables were damaged by blasting or mobile equipment. The data from these are in the data files on the floppy disks but are not felt to be realistic or reliable.

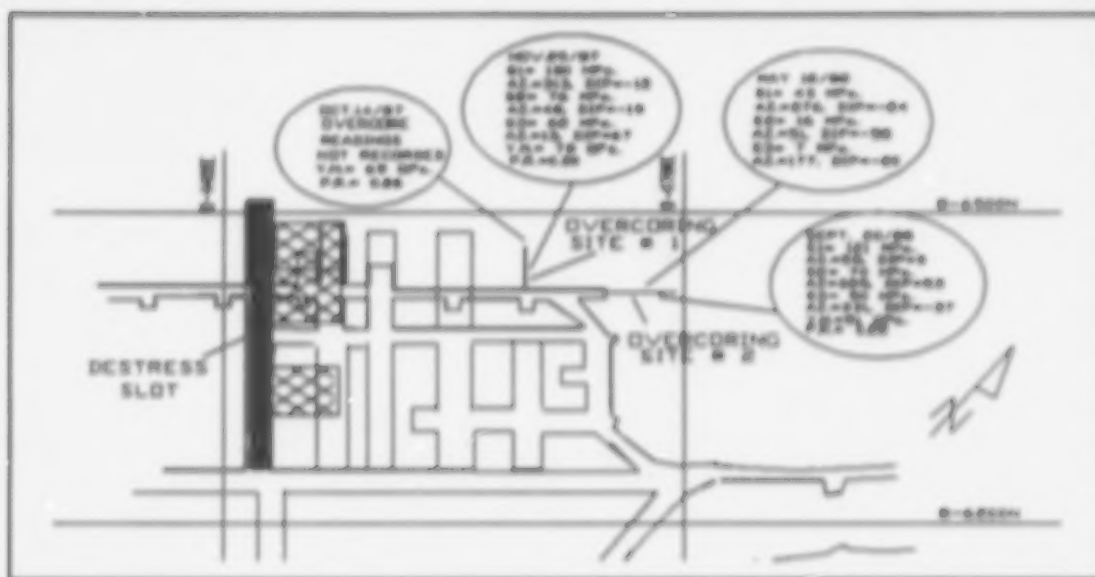


Figure 4-78 6600 Level Plan - Overcoring Stress Measurements

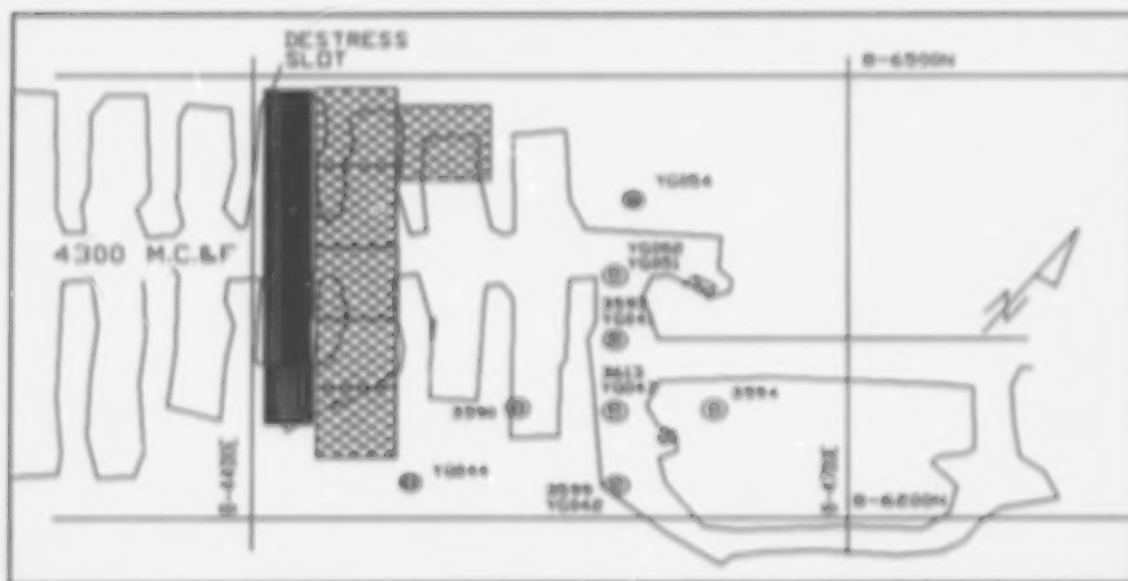


Figure 4-79 6700 Level Plan - HI & Yoke Stress Cell Locations

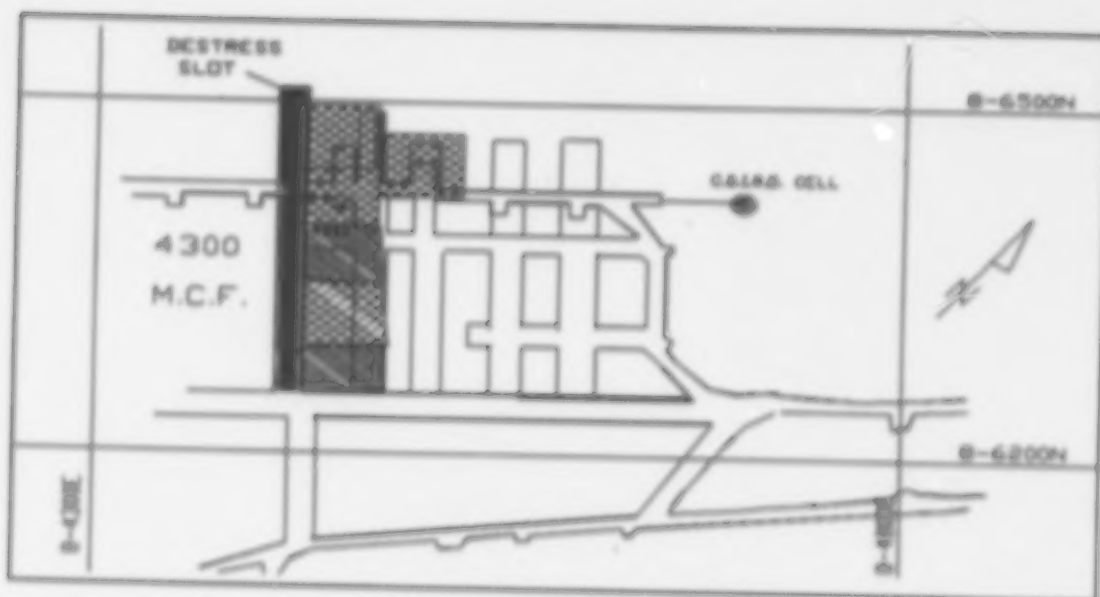


Figure 4-80 6600 Level Plan - HI Stress Cell Location

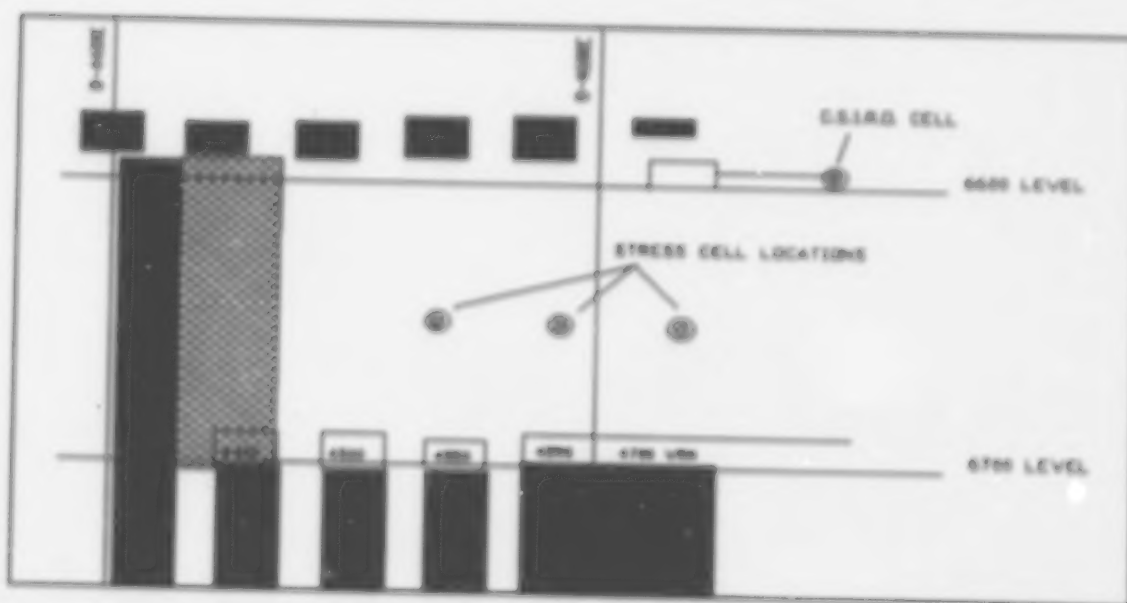


Figure 4-81 Section of Mining Block - Stress Cell Locations

This section of the report gives a detailed explanation of the sequence of mining in 4500 VRM mining block and the surrounding mining areas over the four and one half year duration of the monitoring project. It also presents the monitoring data collected during each stage of the mining in the 4500 block which is analyzed to define the rock mass response to the progressive mining in the monitoring site location.

The information is presented to allow the reader, with the help of the detailed geometric co-ordinance of the pre-monitoring mining given in Volume 4: "Numerical Model Calibration Studies" to reconstruct the step by step mining in lower Creighton Mine that took place during monitoring period. This information along with the detailed analysis of the rock mass response has produced a complex case study that can be used to calibrate and validate any given 3-D numerical code.

The displacement data and borehole television camera logging data collected during this monitoring program is presented in this section of the report in a three dimensional graphical form. This method of presenting the data was chosen to give the reader a pictorial representation (Figure 5-5 to 5-13) of the magnitude and location of the rock mass progressive response to the continued mining. This summary representation of the data will allow the reader to develop an understanding of the rock mass behaviour during the monitoring program without the confusion often caused by mass absorption of detailed measurements.

A plan of 6600 level showing the orientation of the different drill rings that make up the monitoring holes is given as a summary reference in Figure 5-4. The location of the instrumentation and activity is referred to by the drill ring numbers in this section of the report with the actual hole numbers given in brackets. The specific location of the individual holes and the magnitudes and directions measured during the monitoring program are presented in detail in Section 4.0 of this report and/or are available in the data files on the floppy disk that accompany this report.

The stress monitoring data that was collected only in the later part of the monitoring program is presented as strain data plotted against project days (Figure 5-57) to demonstrate the magnitude and timing of the stress change in relation to specific mining events.

The above data was collectively used along with other visual data to estimate the location of the stress relaxation zone at each stage of mining during the monitoring period. The location of the relaxation zone is indicated in plan and section by hatch line as shown in Figure 5-13.

5.1 Pre-Monitoring Mining

The monitoring program in 4500 VRM mining block did not start until after the destress had been completely mined. The pre- destress slot and the post-destress slot mining states (Figures 5-1 and 5-2) are used as part of the Volume 4: "Numerical Model Calibration Studies" but were not mined during the monitoring period.

The pre-destress slot mining state was used in the calibration because at this stage of the cut and fill mining in the 400 ore body both crown pillars between 6800 and 6600 levels and 7000 and 6800 levels were assumed to be intact. This mining state was ideal to back analyze as a first estimate of the proper rock mass input properties needed to realistically simulate the rock mass response to mining with the numerical codes. The post-destress slot mining state was also used primarily because the initial site investigation had allowed the location of the stress relaxation zone in 4500 VRM mining block to be well defined. This again was an ideal condition to be used as a check on the input properties given the different numerical codes used in the model calibration study.

The different stages of mining that were used in the Volume 4 calibration study are indicated in brackets in the sub-section titles.

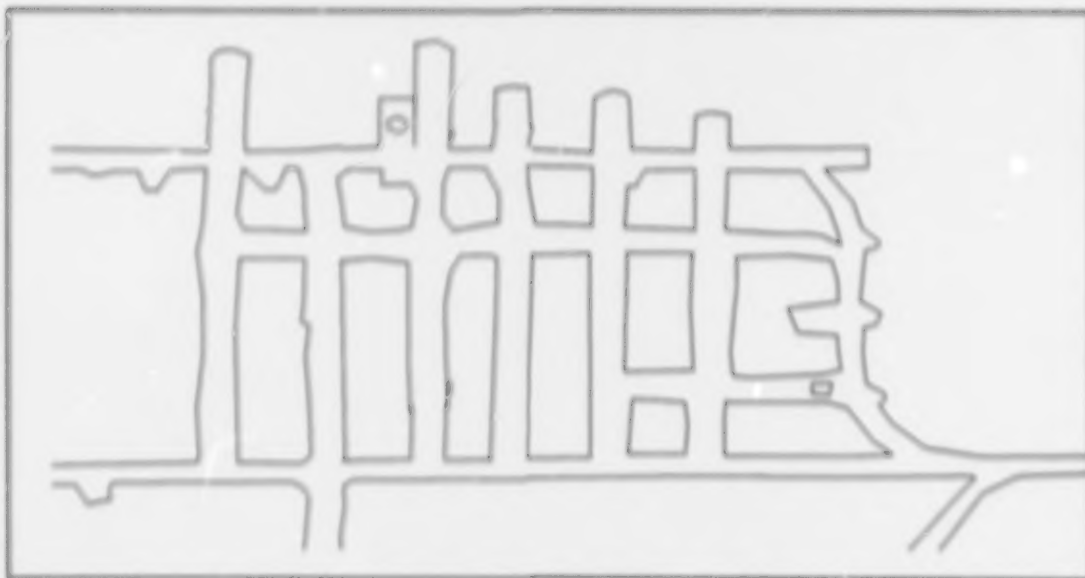


Figure 5-1 Pre-Destress Slot Mining State



Figure 5-2 Post-Destress Slot Mining State

5.2 4461 VRM Panel Mining (Mining Stage Three)

The first VRM panel, 4461 panel in 4500 block (Figure 5.3), was mined between May 12 and June 17, 1987. Unfortunately, only a small portion of the instrumentation was in place at that time. Five solid rod extensometers were grouted in each of two holes drilled along 4469 Section (Figure 5-4) while three extensometers and an inclinometer casing were in place in one hole drilled along 6400 Section.

Cut and fill mining had continued on the 4300 side of the destress slot, resulting in the crown being reduced in thickness to 25 meters. The 7000 to 6800 MCF crown had been mined to 34 meters from 6800 level.

5.2.1 Displacement

The extensometer results did not indicate any rock mass movement (Figures 4-28 to 4-30) in 4500 VRM block until the last 12 meters of ground in 4461 panel was removed in the crown blast. The extensometer anchor closest to the panel in the Section 4469 holes (38 meters from the collar of hole 75402) showed rock mass displacements of 0.8 mm. along the hole axis towards 4461 panel. The remainder of the rods in this hole showed no movement.

The anchor at the same depth in the second Section 4469 hole (38 meters from the collar of 75403 hole) showed axial movement of 0.6 mm. towards 4461 panel. The only rod in this hole anchored closer to the panel (34 meters) was damaged prior to the blast and could not be read. The remaining rods in the hole showed no movement taking place during the mining of this panel.

The three extensometer rods in the 6400 Section hole were damaged prior to the last blast in 4461 panel and reliable readings could not be obtained. The pre-damage readings did not show any rock mass movement. An inclinometer probe was run down the casing in the 6400 Section hole several times during and after the mining of 4461 panel to measure the vertical and horizontal displacement in respect to the hole axis. The data collected did not show any displacement in the hole during the mining period.

A three dimensional representation of the displacement data is shown in Figures 5-5, 5-6 and 5-7.

5.2.2 Stress Measurements

A total of four attempts at overcoring C.S.I.R. stress cells were made at the Site 1 location in the hangingwall of 6420 drift on 6600 level during this mining stage. The one successful stress measurement was overcored on Nov. 25, 1987, between the mining of the first and second panels in 4500 VHM block. The magnitudes and directions of the principal stresses from this overcoring and a successful Hoek cell test from one of the other earlier overcoring attempts are shown in Figure 4-78. This site was abandoned after that overcoring subsequent drilling failed to produce suitability location in the disseminated norite in which to install a stress cell.

5.2.3 Borehole Logging After 4461 Panel Mining

The initial logging of the boreholes drilled in 4500 V.R.M block was performed between Sept. to Dec. 1987. The visual observations made during the logging of the holes are recorded in the data files on the accompanying floppy disks. A 3-D representation of the highly fracture areas and the sections of hole that were spalled and the direction of the principal stress that caused the spalling is shown in Figures 5-8 to 5-13.

The highly fractured zones in 4500 block indicates that the stress relaxation zone was pushed out approximately 6 meters past the edge of 4461 panel. This was confirmed by the drilling of 4501 panel a year and a half later. The holes drilled on the destress slot side of 4501 panel showed no signs of squeezing, while the holes drilled in the other side of the panel were all spalled due to high stress conditions.



Figure 5-3 6600 Level Plan - 4461 Panel Mining

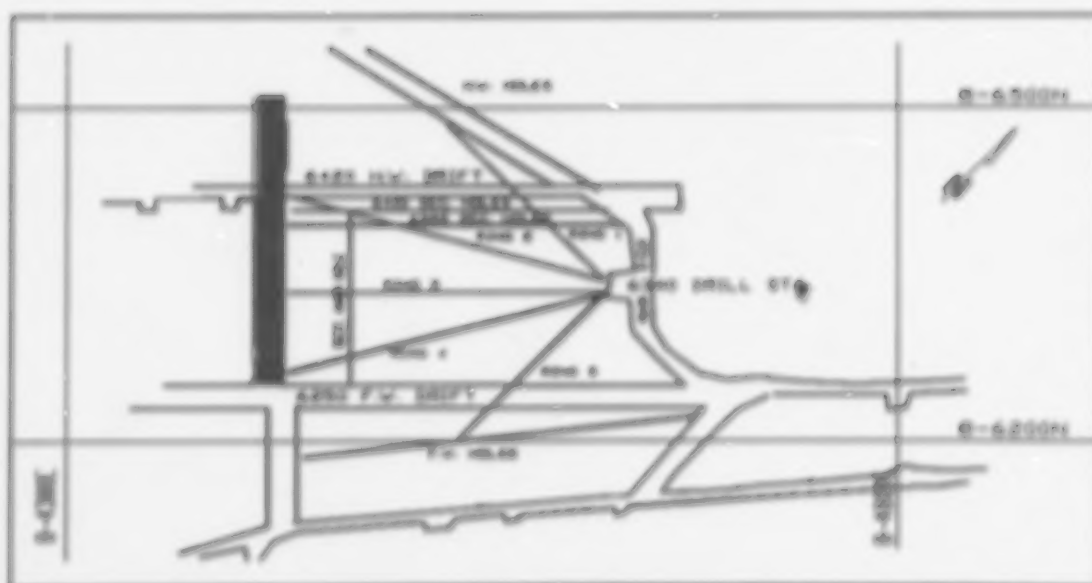


Figure 5-4 6600 Level Plan - Monitoring Hole Drill Rings

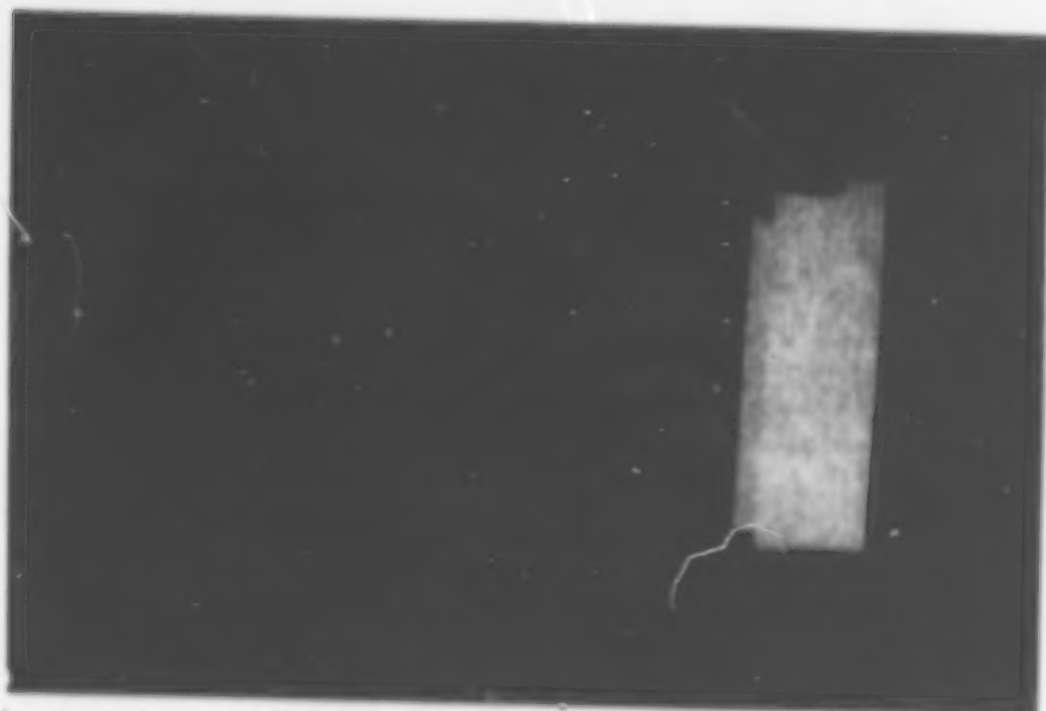


Figure 5-5 3-D South View - Axial Displacements - 4461 Panel

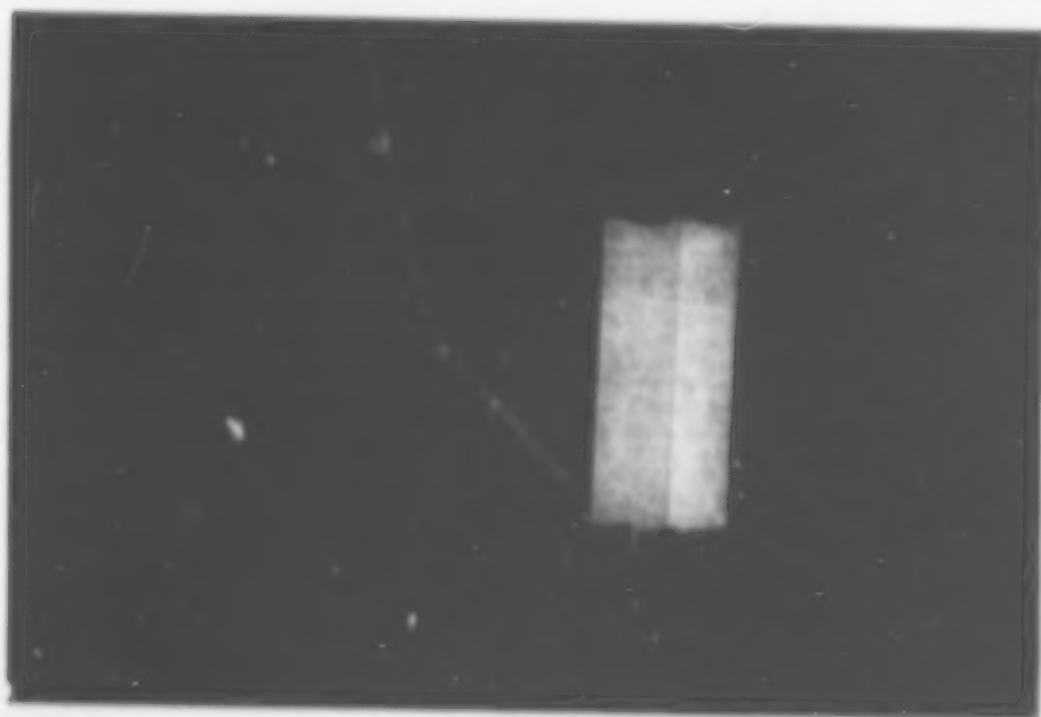


Figure 5-6 3-D South-E View - Axial Displacements - 4461 Panel

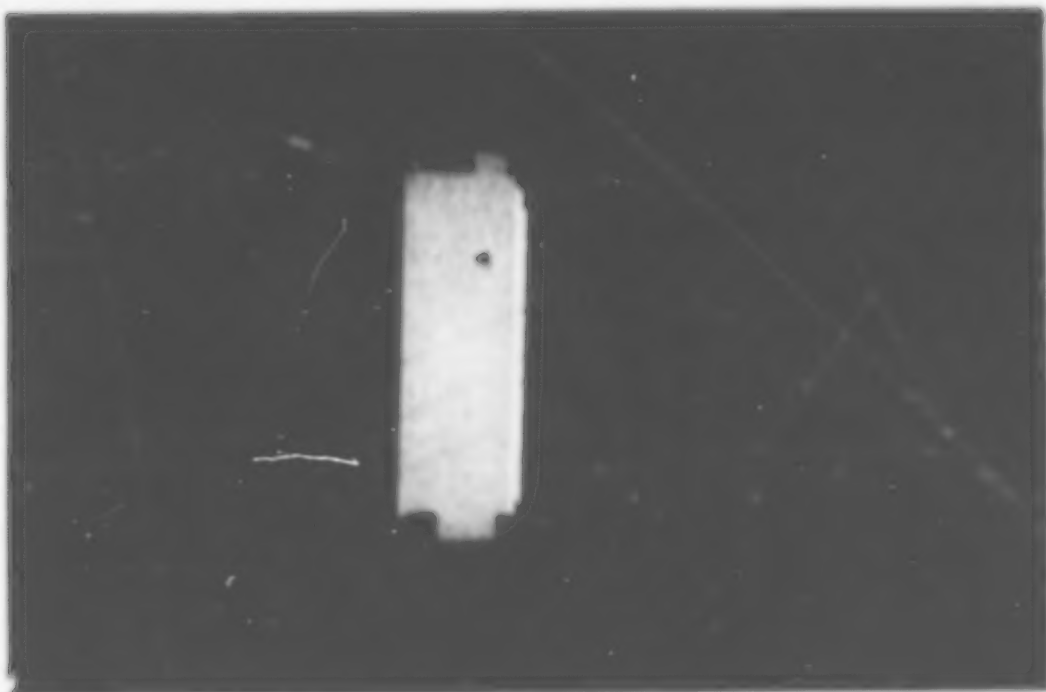


Figure 5-7 3-D East View - Axial Displacements - 4461 Panel

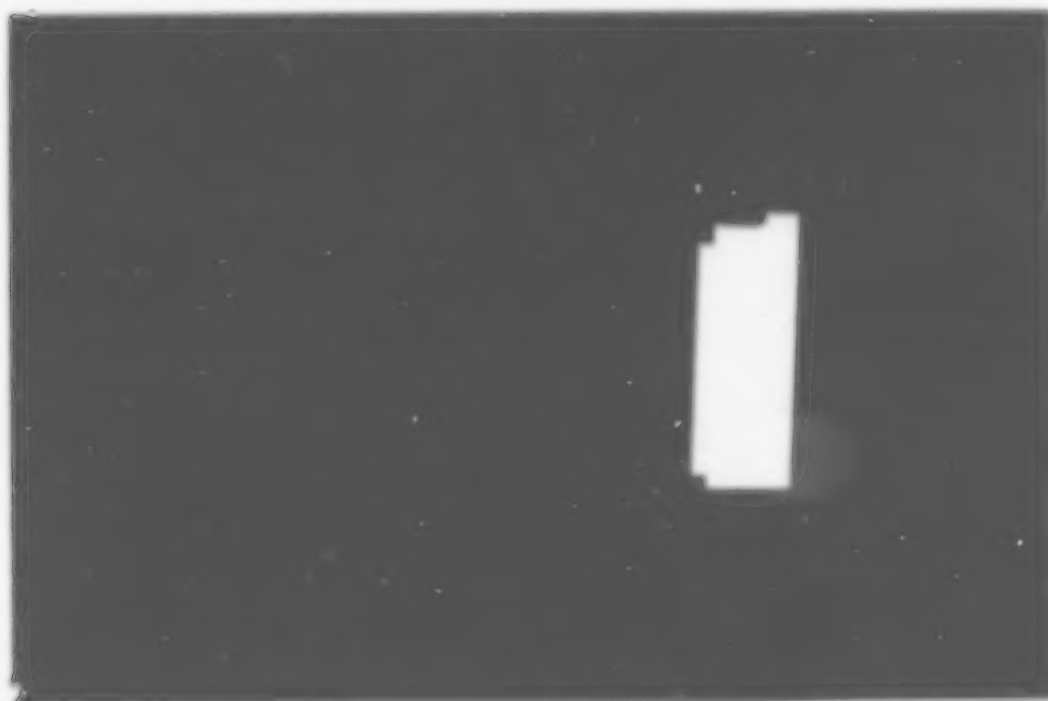


Figure 5-8 3-D South View - Highly Fracture Zones - 4461 Panel

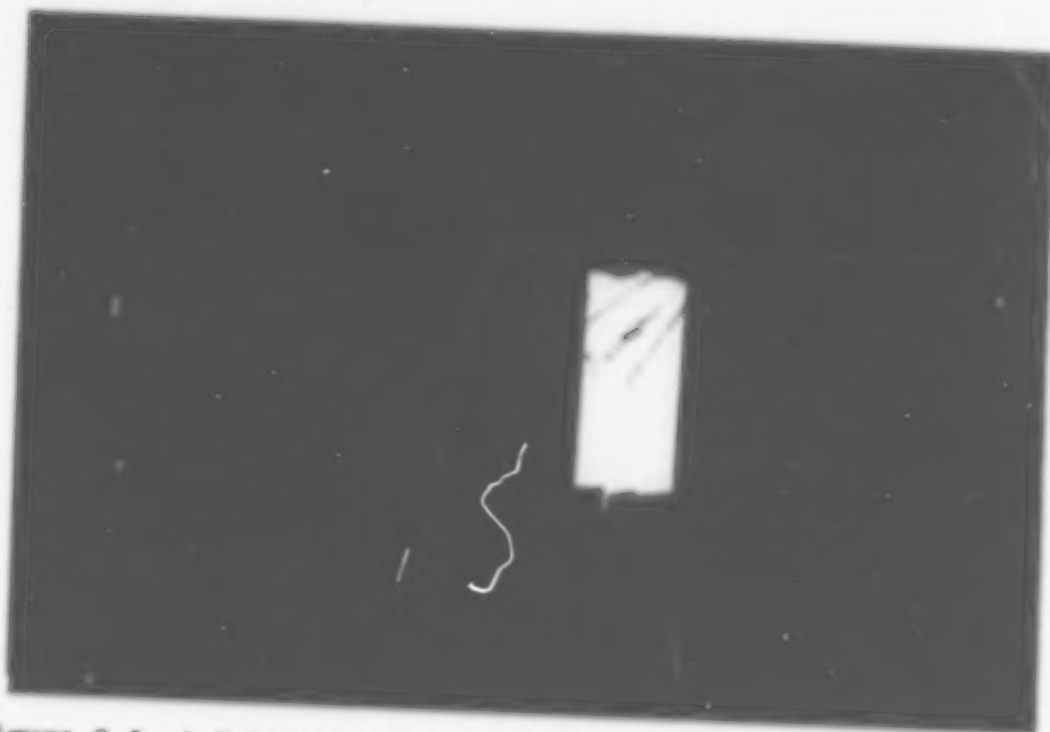


Figure 5-9 3-D South-E View - Highly Fracture Zones - 4461 Panel



Figure 5-10 3-D East View - Highly Fracture Zones - 4461 Panel

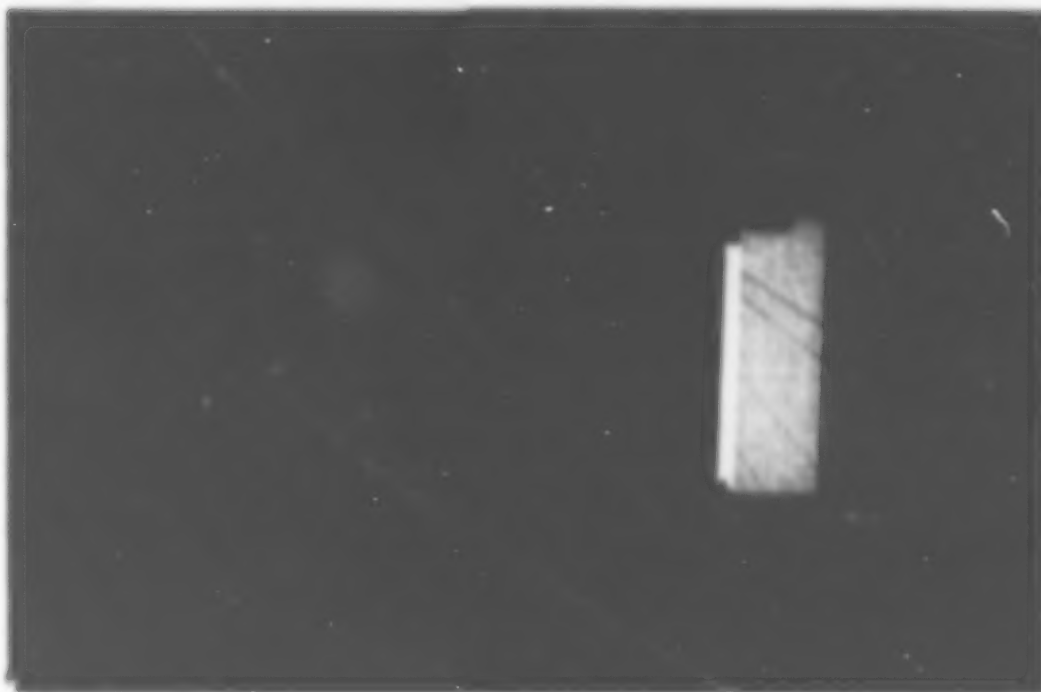


Figure 5-11 3-D South View - Borehole Spalling - 4461 Panel



Figure 5-12 3-D South-E View - Borehole Spalling - 4461 Panel

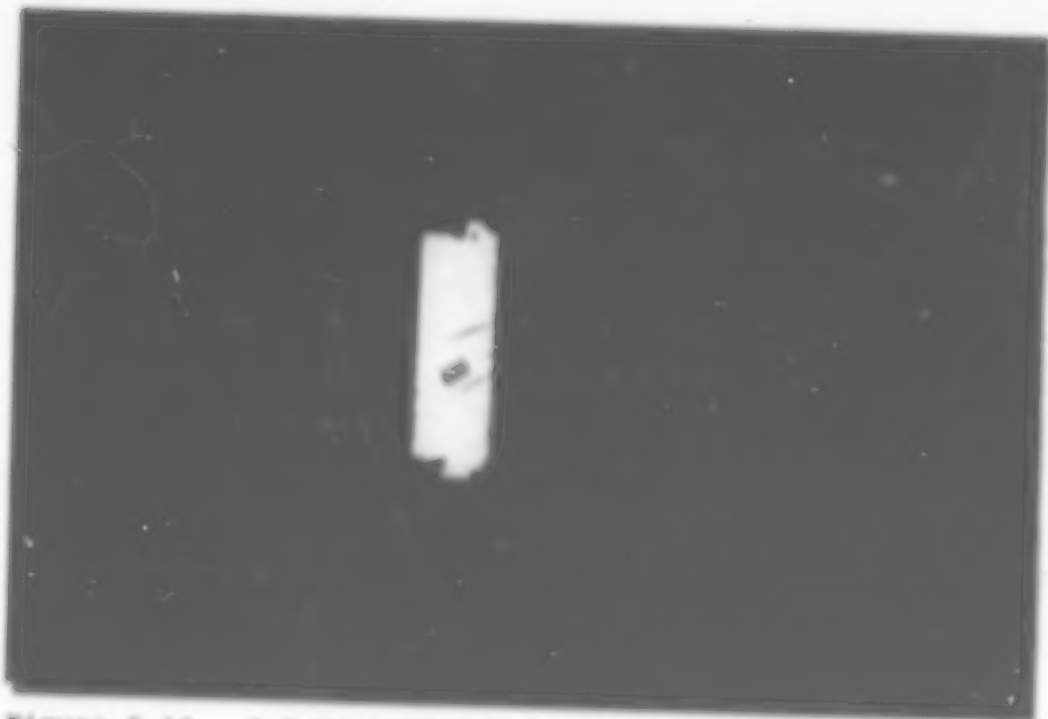


Figure 5-13 3-D East View - Borehole Spalling - 4461 Panel

This high stress and squeezing information indicates that the interface between stress relaxed and the highly stressed rock mass ran approximately down the centre of 4501 panel which agrees with the estimate made from the borehole logging data.

The mining of 4461 panel did not appear to extend the relaxation zone anywhere other than the immediate location of the panel. The area of high stress indicated by the spalled zones shows that the centre section of the monitoring site was not stress relaxed. An estimate of the location of the stress relaxation zone after the mining of 4461 panel is shown by the hatching in Figure 5-14.

5.3 4462 V.R.M. Panel Mining (Mining Stage Four)

Panel 4462 was mined in 4500 V.R.M. block (Figure 5-15) between Feb. 2 and Mar. 3, 1988 and was the second panel of ore removed from the monitoring site. The drilling of the boreholes for instrumentation installation and rock mass inspection had been completed on 6500 level in 4500 block prior to the start of mining in this panel but not all the displacement monitoring instrumentation had been put in place. Consequently, the displacement data covers only a portion of the actual mining period.



Figure 5-14 Stress Relocation Zone Location - 4461 Panel Mining



Figure 5-15 6400 Level Plan - 4462 Panel Mining

The mining of 4402 panel was delayed because of damage to the 4000 level ore haulage drift that handled the ore from this area. The drift was damaged during a rock burst that occurred in October, 1987 which was assumed to be the result of a section of the 4300 M.C.F. crown pillar between 4000 and 4400 failing. The source location for the burst event and associated smaller events indicated that a major stress redistribution had occurred in the crown pillar. The crown had been mined to 25 meters which is the historic thickness for M.C.F. crown failures at this depth.

The crown between 7000 and 4000 was mined to 33 meters before 4402 panel was mined.

9.3.1 Displacement

Additional instrumentation was put in place prior to the mining of 4402 panel. Extensometer rods and inclinometer casings were installed in two holes (Figure 5-4) drilled on 6385 Section (75422 and 75424 holes, Figures 4-9 to 4-18) and monitored over the entire mining period. The same instrumentation was installed in the 4400 Section and several Ring 2 and 4 holes (75446, 75438, 75432 and 75431 holes) but only the inclinometer readings were taken in all these holes before the panel was completely mined. The multi-point extensometers were not equipped with measuring heads in most of the holes until mining was completed. Only the rods in one of the 4400 Section holes and one Ring 2 hole (75446 and 75432 holes) had measuring heads prior to the crown blast in 4402 panel.

The extensometer rods in two of the other 4400 Section holes (75402 and 75403 holes) were being monitored by data logger during the mining of the first panel. Problems with these loggers resulted in these rods being equipped with reading heads and manually monitored for the last part of the mining of the panel only. The poor condition of these measuring heads was due to the area being extremely wet which left the accuracy of the data collected from these holes in suspect. This has resulted in it being excluded from the rock mass response evaluation for the mining of this panel. These two holes were destroyed by development mining shortly after 4402 panel was completed.

The axial displacement measured in the 4400 Section and 6385 Section holes indicated that displacements of 0.5 to 2.0 mm. took place in lower sections of these holes near the end of the mining in this panel (Figures 9-14 to 9-16).

The direction of displacement was away from the hole collar toward the mining. The displacement of 15 mm. in the 40 meter anchor point in the deepest 6385 Section hole (75422 hole) is thought to be related to the displacement of a slab of ore in the wall of the panel that contained the extensometer anchor.

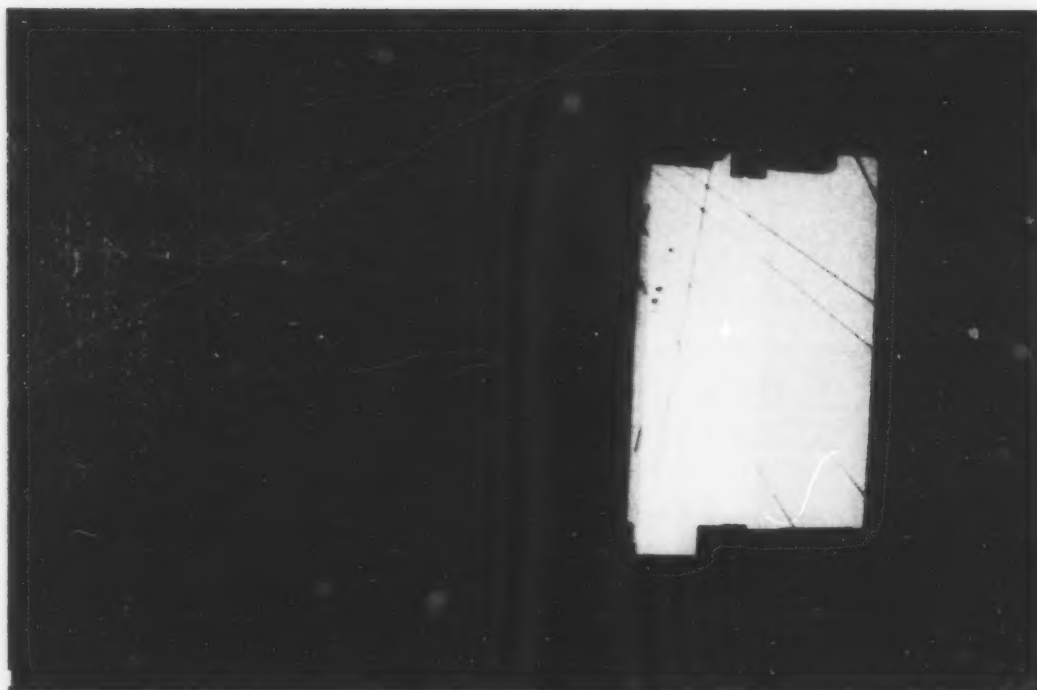


Figure 5-16 3-D South View - Axial Displacements - 4462 Panel

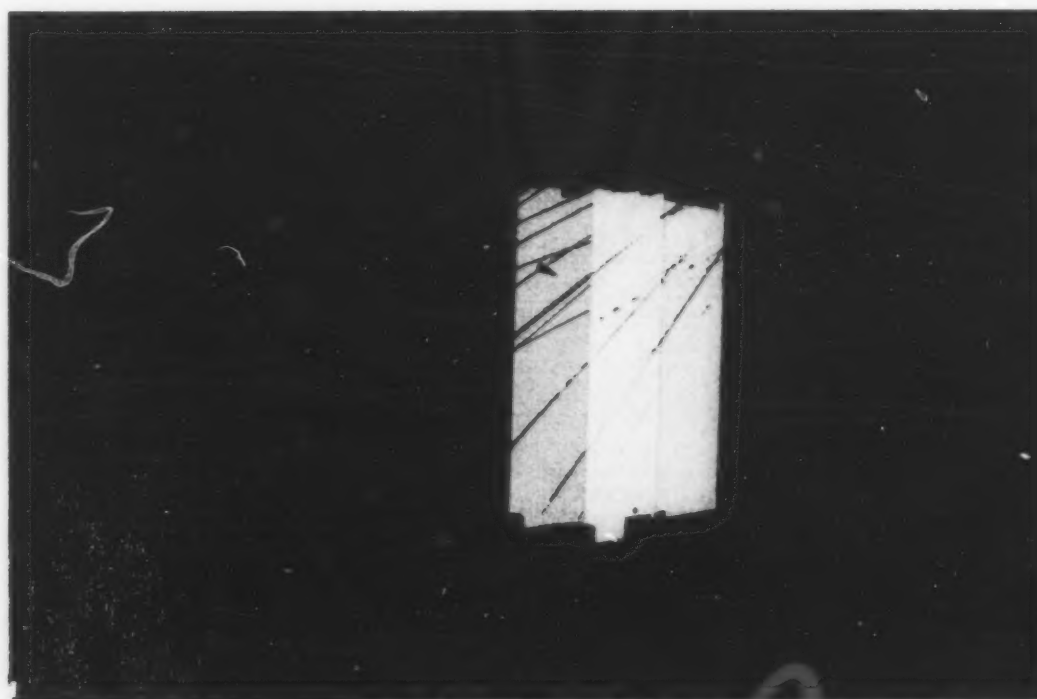


Figure 5-17 3-D South-E View - Axial Displacements - 4462 Panel

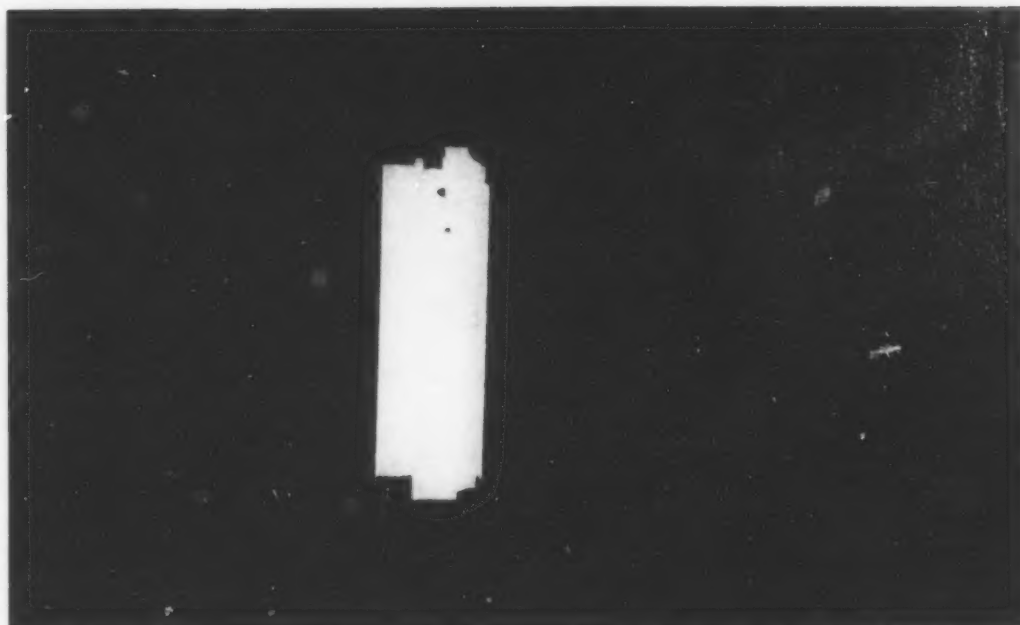


Figure 5-18 3-D East View - Axial Displacements - 4462 Panel

The displacement data from the inclinometer probe early on in the monitoring program had a considerable amount of noise associated with it (Figures 4-47 to 4-66). This is due to the contamination of the inclinometer casings with the cement used to grout the casings into place.

The inside of casings were repeatedly scraped and flushed with water to remove the contamination which eventually improved the problem. The inclinometer reading taken at the beginning of the monitoring program reflect the noise in the data as a result of the contamination and consequently fluctuate wildly. Due to this early inaccuracy no realistic displacements changes can be interpreted from the data collected with the inclinometer during the mining of 4462 panel.

5.3.2 Stress Measurements

Following the mining of the 4462 V.R.M. panel, a stress measurement was made on 6600 level by installing and overcoring two C.S.I.R. triaxial hollow inclusion stress cells at overcoring site 2 (Figure 4-67). The magnitudes of the principal stresses from this overcoring were much lower than the previous measurement taken from overcoring site 1 prior to the mining of this panel.

5.3.3 Borehole Logging After 4462 Panel Mining

When mining of 4462 panel was complete the inspection boreholes located just in the general vicinity of the panel were logged with a borehole camera. Many of the holes logged earlier now contained instrumentation and could not be re-logged while others could not be logged due to time constraints between panels mined.

A 3-D representation of the visual observations made in these holes is given in Figures 5-19 to 5-24. The location of the areas of highly fractured rock mass suggest that the mining of the second panel in the monitoring site caused the stress relaxation zone to again be pushed out only in the area of mining. The new areas of highly fractured rock mass are located adjacent to 4462 panel and close to 6600 level some distance in front of the mined out zone. The centre section of the monitoring site again underwent an increase in stress as indicated by the increased in spalling observed in several of the holes. This demonstrates that this section of the block was still not in a stress relaxed state before this panel was mined which agrees with the interpretation of the initial logging data. The new location of the stress relaxation zone has consequently been interpreted as shown in plan and section by the hatched lines in Figure 5-25.

5.4 4464 V.R.M Panel Mining (Mining Stage Five)

The third panel mined in 4500 V.R.M. block, shown in Figure 5-26, was excavated between May 14 and August 12, 1988. This period of mining includes a one month vacation shutdown in July during which no mining took place in Creighton Mine. It was at this stage in the monitoring program that 4300 mining block to the west of the destress slot was converted from the mechanized cut and fill mining method to the vertical retreat method. The initial V.R.M. panel mined in this block (Figure 5-26) was excavated over the same general time period as the 4464 panel mining. The M.C.F. crown between 7000 and 6800 levels was mined to 30 meters below 6800 level at this stage in the monitoring program.

The mining plans for the development of 4500 block on 6600 level were revised prior to the mining of this panel. The subsequent development resulted in the instrumentation in the Section 4469 holes (Figure 5-4) being lost when the holes were intersected. The instrumentation in one of the 6400 Section holes (75419 hole) was also destroyed when struck by mobile equipment. The instrumentation in the remaining holes was monitored throughout the mining of 4464 panel. The development plans on 6700 level were also revised due to the deterioration of the ground in the access drifts. The sixth cut of the previous cut and fill mining, which was used for access to the mining area on 6700 level, was backfilled and the level re-developed on the seventh cut as shown in Figure 5-27.

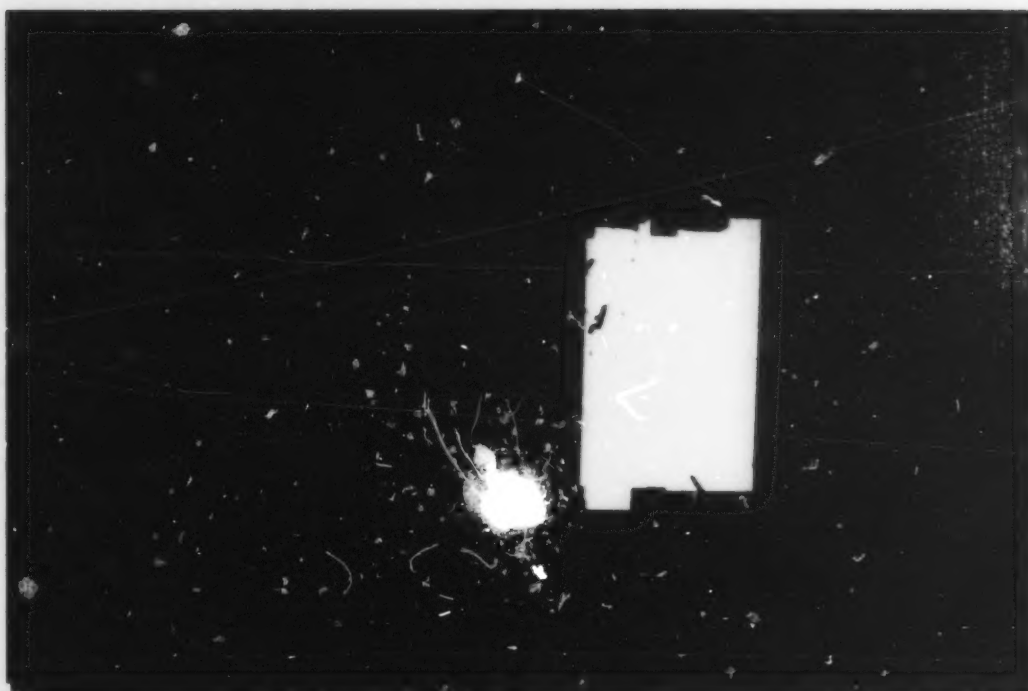


Figure 5-19 3-D South View - Highly Fracture Zones - 4462 Panel

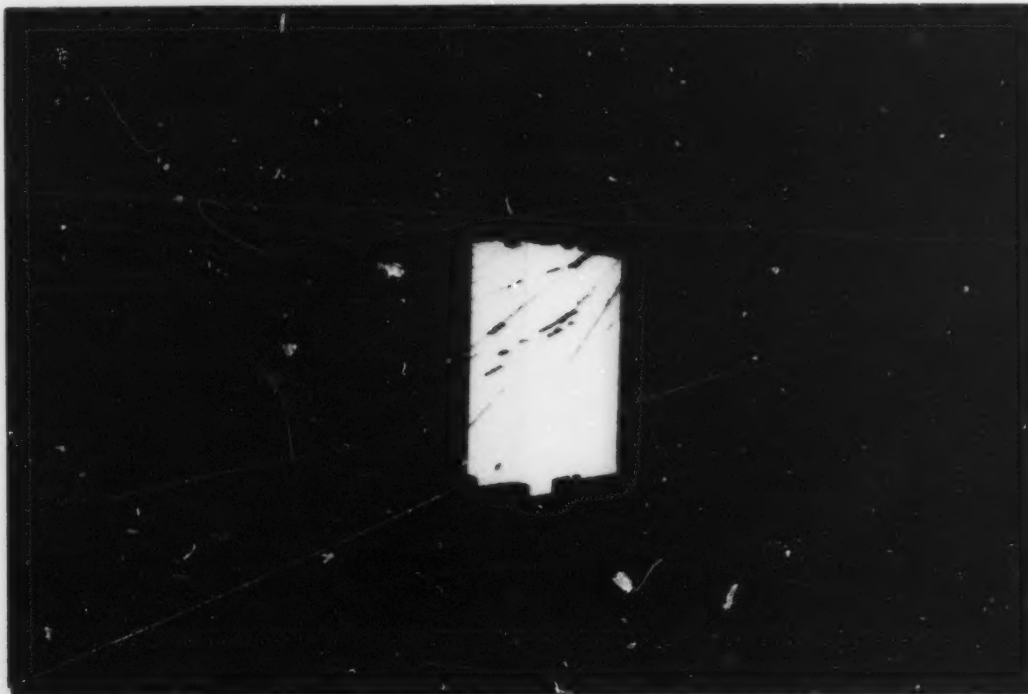


Figure 5-20 3-D South-E View - Highly Fracture Zones - 4462 Panel

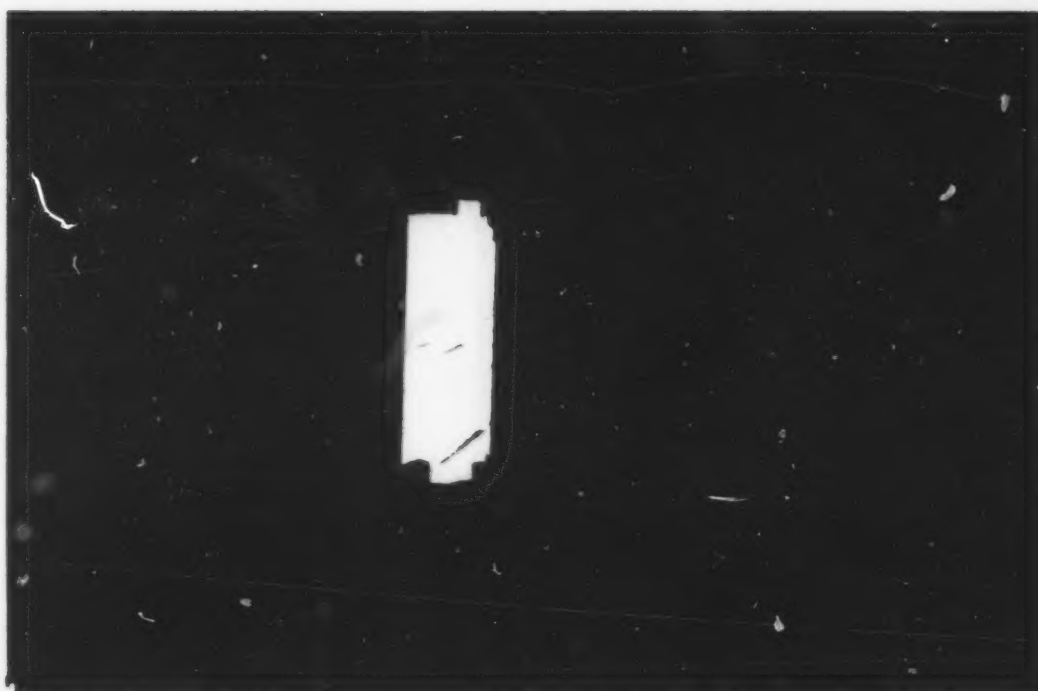


Figure 5-21 3-D East View - Highly Fracture Zones - 4462 Panel



Figure 5-22 3-D South View - Borehole Spalling - 4462 Panel



Figure 5-23 3-D South-E View - Borehole Spalling - 4462 Panel

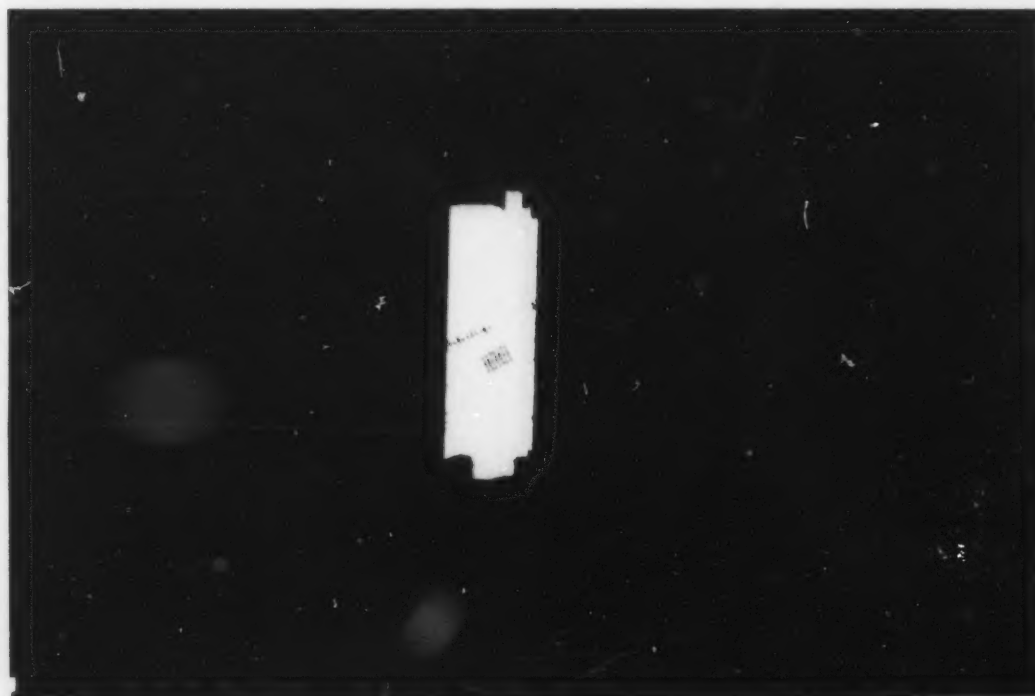


Figure 5-24 3-D East View - Borehole Spalling - 4462 Panel

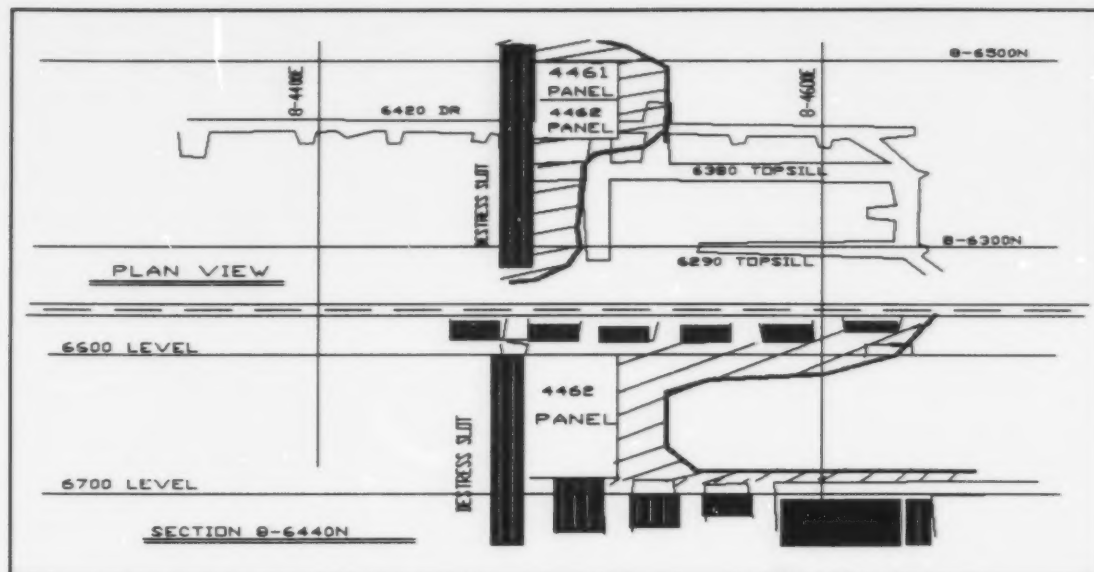


Figure 5-25 Stress Relaxation Zone Location - 4462 Panel Mining

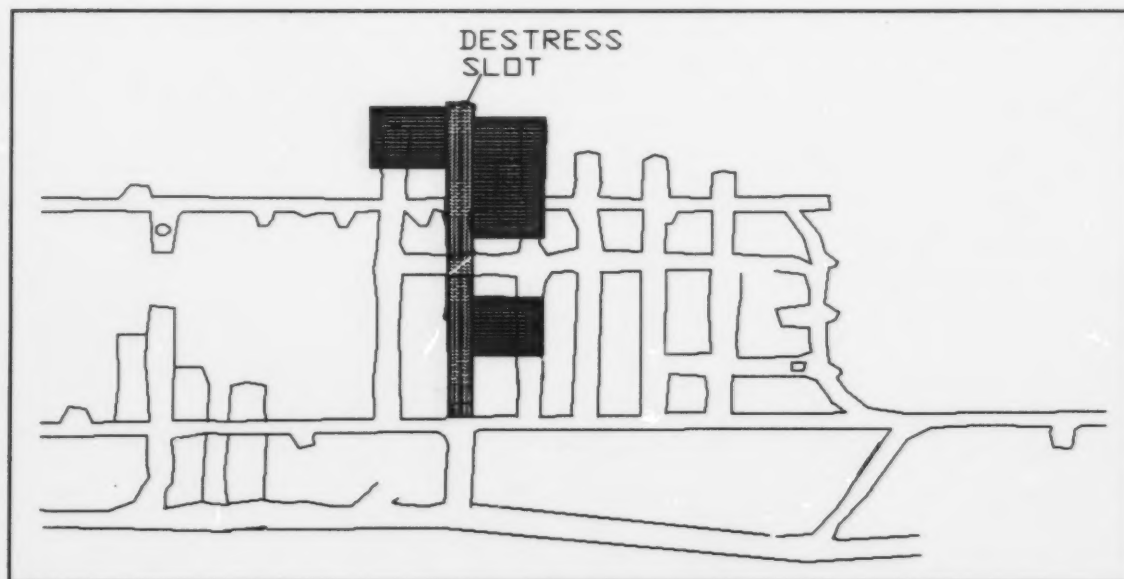


Figure 5-26 6600 Level Plan - 4464 Panel Mining

The backfilling did not take place until after the mining of the 4464 panel but the initial development of the seventh cut was being conducted while 4464 panel was being mined.

5.4.1 Displacement

Axial displacements of between 1 and 3 mm were measured at extensometer anchor points throughout the monitoring site during the mining of the third panel (Figures 5-28 to 5-30).

The anchors in the top hole (75422 hole dipping 22 degrees) in the drill ring on 6385 Section (Figure 5-4) initially showed axial displacement away from their collars and towards the distress slot and the panel being mined. The direction of displacement changed, however, as the excavation of 4464 panel progressed. Part way through the panel mining the anchors started to show movement towards the collar of the hole.

The movement measured in a second hole drilled on 6385 Section (hole 75424 dipping at 60 degrees) showed axial displacements away from the hole collar. This hole was drilled at a steeper angle and was monitoring a smaller portion of the monitoring site which would account for the difference in the direction of the axial displacements measured in these two holes.

The extensometer anchors in the Ring 1 hole, which are located in the same section of the monitoring site as the anchors installed on 6385 Section but at a different orientation, showed movement away from their collar in the rods anchored at 9 to 15 meters in the hole. The rods anchored from 30 and 39 meters showed axial movement towards the hole collar. The remaining anchors which were all in the vicinity of Section 6385 hole (18 and 24 meters) showed little to no movement. The deep anchors in this hole located in the hangingwall showed little to no axial movement in that location in the rock mass.

The axial displacement measured in one of the monitoring holes drilled in Ring 2 (hole 75432) showed small displacements throughout the monitoring program. This is mainly due to the steep orientation (dipping 80 degrees) of this hole. The displacement associated with the V.R.M. mining in 4500 block is primarily in a planer direction due solely to the geometry of the excavation and field stress magnitudes and orientations. Consequently, the majority of the displacement was measured in the flatter holes.

A second hole drilled in Ring 2 (hole 75431 dipping at 50 degrees) shows similar movement but much lower magnitudes. The measurements from the anchor at the 15 meter depth in this hole continually shows an erratic displacement at this depth with the continued mining. This has been attributed to a poorly mounted measuring head on the extensometer rod.

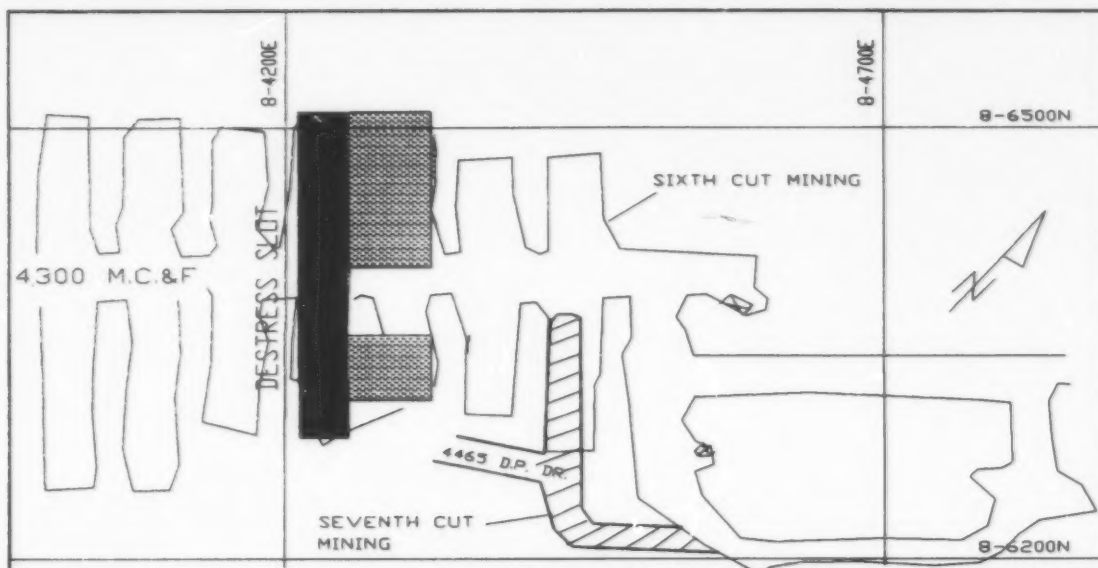


Figure 5-27 6700 Level Plan - Seventh Cut Development

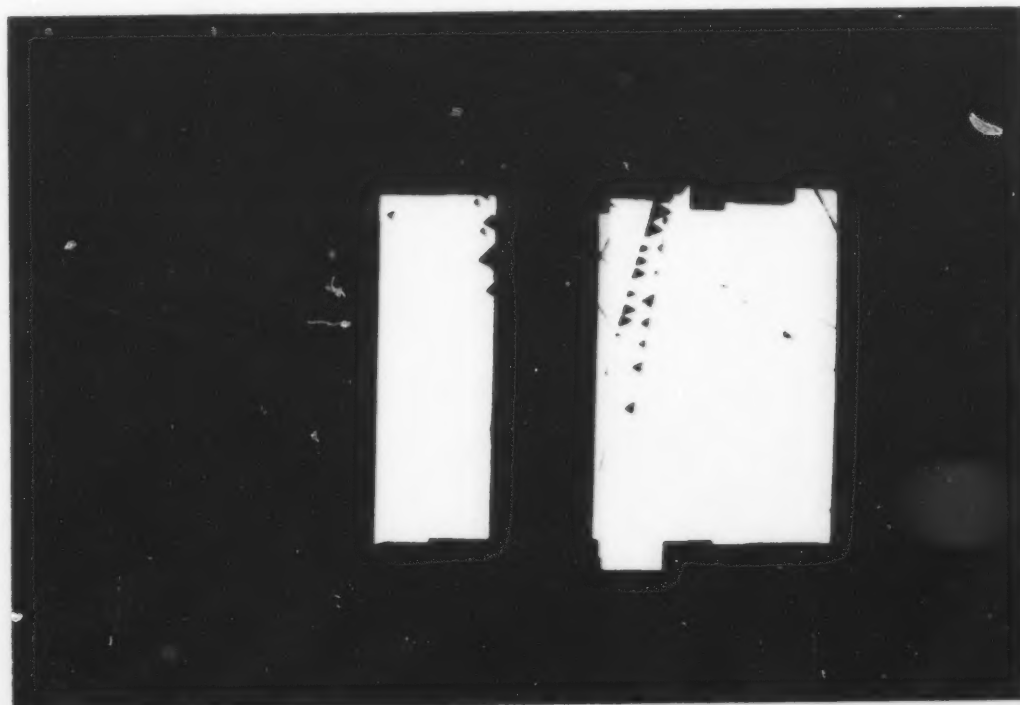


Figure 5-28 3-D South View - Axial Displacements - 4464 Panel



Figure 5-29 3-D South-E View - Axial Displacements - 4464 Panel

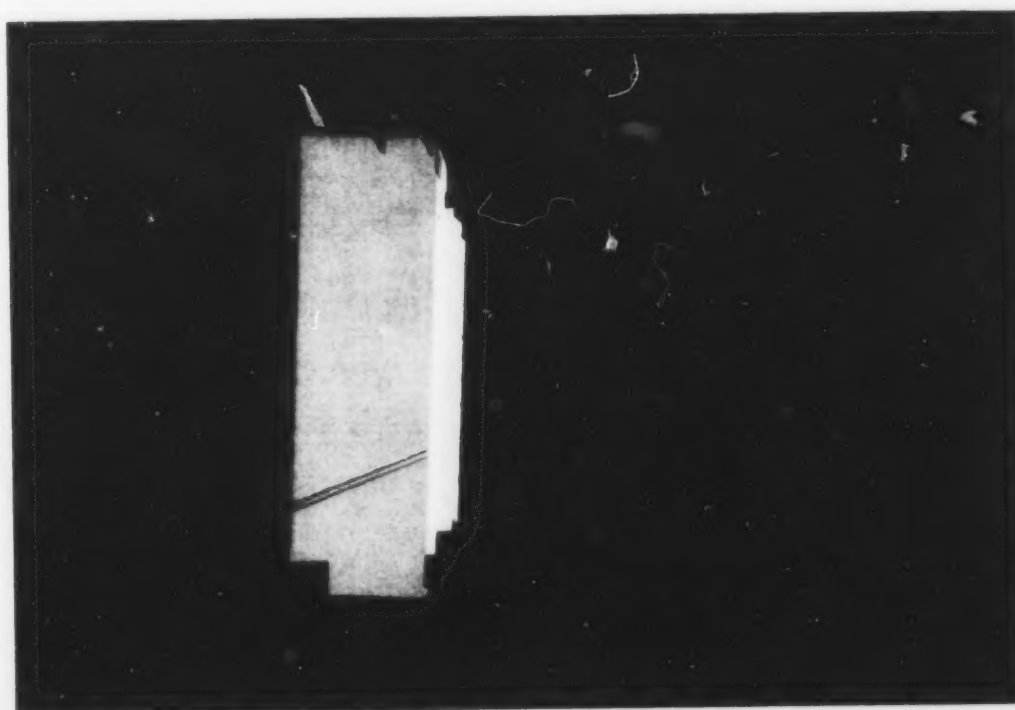


Figure 5-30 3-D East View - Axial Displacements - 4464 Panel

Both holes in this ring showed the greatest anchor displacement as a result of the crown being removed from 4464 panel.

There appears to have been a substantial amount of noise in the axial displacement measurements taken in the extensometer monitoring hole drilled in Ring 4 (hole 75438) during the mining of 4464 panel making the interpretation of the data difficult.

The displacements measured at these anchor locations in the monitoring site, however, are small. The axial displacements measured in Ring 5 (hole 75441) were also of a low magnitude which indicates that this footwall section of the monitoring site was less effected by the mining of 4464 panel than the remainder of 4500 VRM mining block.

The inclinometer data at this stage of the monitoring still contained too much noise to allow reliable conclusions to be drawn. The data was, therefore, not used in the evaluation of the rock mass displacement response to this stage of the mining.

The majority of the displacement took place in the area of the monitoring block closer to the hangingwall even though the panel mined was closer to the footwall. This indicated that the changes in stress and migration of the relaxation zone would also be greater in this section of the monitoring site. It was the mining of this panel that caused the stress relaxation zone to migrate out the full length of the destress slot to approximately 5 meters out from the edge of 4464 panel as shown in Figure 5-31.

5.4.2 Stress Measurements

Three C.S.I.R.O. stress cells were overcored at the site 2 located on 6600 level after the mining of 4464 panel. Only one of these three was successful (Figure 4-78) and shows the magnitudes of the principle stresses to be substantially higher than the previous overcore completed before the mining of 4464 panel.

5.5 4501 V.R.M. Panel Mining

Panel 4501 (Figure 5-32) was the fourth panel to be mined in 4500 V.R.M. block and was excavated between Nov. 2 and Dec. 2 1988. This panel was still mined from the sixth cut on 6700 level and after the initial stage of development mining for the seventh cut was completed. The second panel on the 4300 side of the destress slot was mining over the same general period on mining.

The 7000 to 6800 level mechanized cut-and-fill mining of the crown extended upward 27 meters from 6800 level.

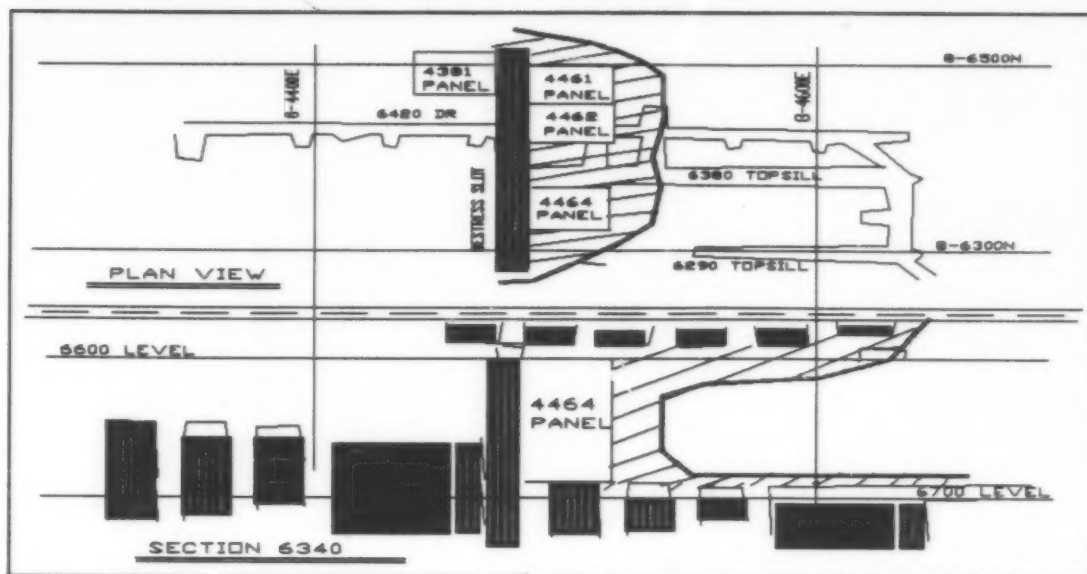


Figure 5-31 Stress Relaxation Zone Location - 4464 Panel Mining

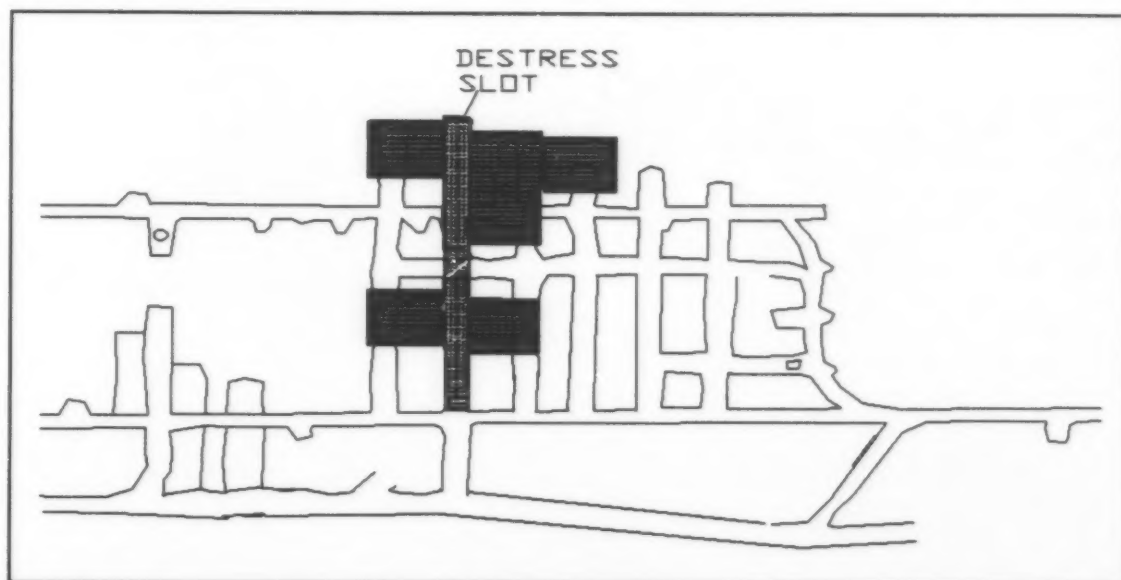


Figure 5-32 6600 Level Plan - 4501 Panel Mining

5.5.1 Displacements

The displacements of the extensometer anchors in the holes drilled on (Figure 5-4) 6385 Section and Rings 1 and 2 (holes 75422, 75424, 75427 and 75431) showed the greatest axial movement which ranged from 1 to 4.5 mm in magnitude (Figures 5-33 to 5-35). All these holes are located in the vicinity of 4501 panel and showed axial movement away from their collars with the exception of the top hole drilled on Section 6385 (hole 75422) which again displaced towards the collar of the hole. The rod anchored at 27 meters in this hole appeared to stop functioning properly for some unknown reason at this stage of the mining which is reflected in all subsequent readings.

The axial displacement in the remainder of the holes, which are located farther away from 4501 panel toward the footwall, ranged from 0.5 to 1 mm. The exception to this were the rods anchored in the lower section of extensometer monitoring hole drilled in Ring 4 (hole 75438) which are located directly above the seventh cut development on 6700 level in the vicinity of a major fracture that was demonstrating movement at the time.

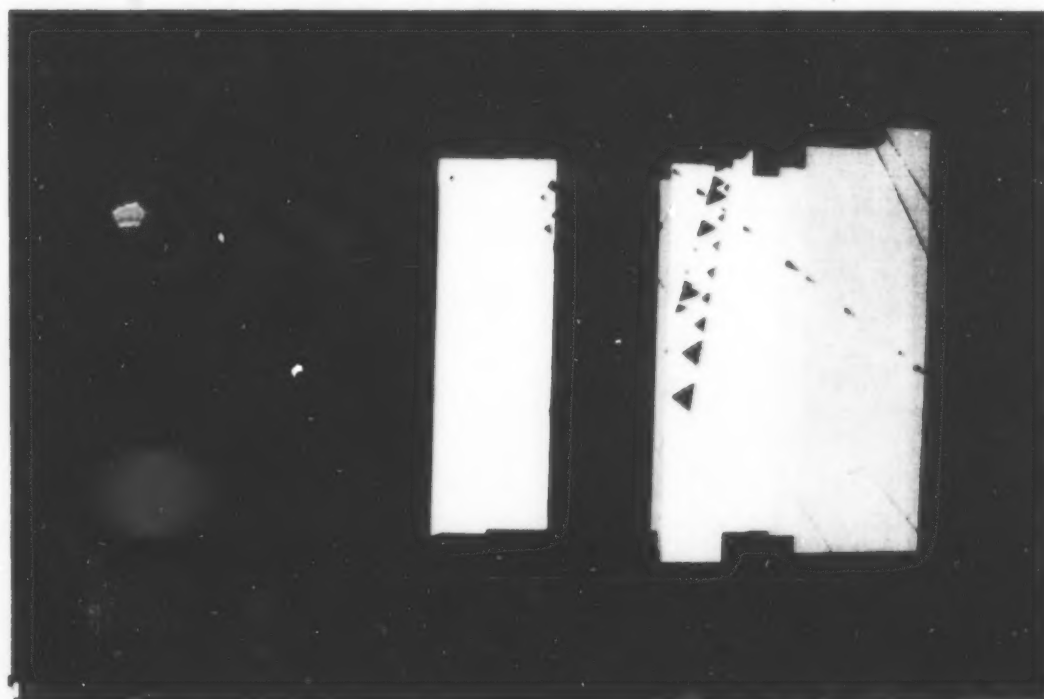


Figure 5-33 3-D South View - Axial Displacements - 4501 Panel

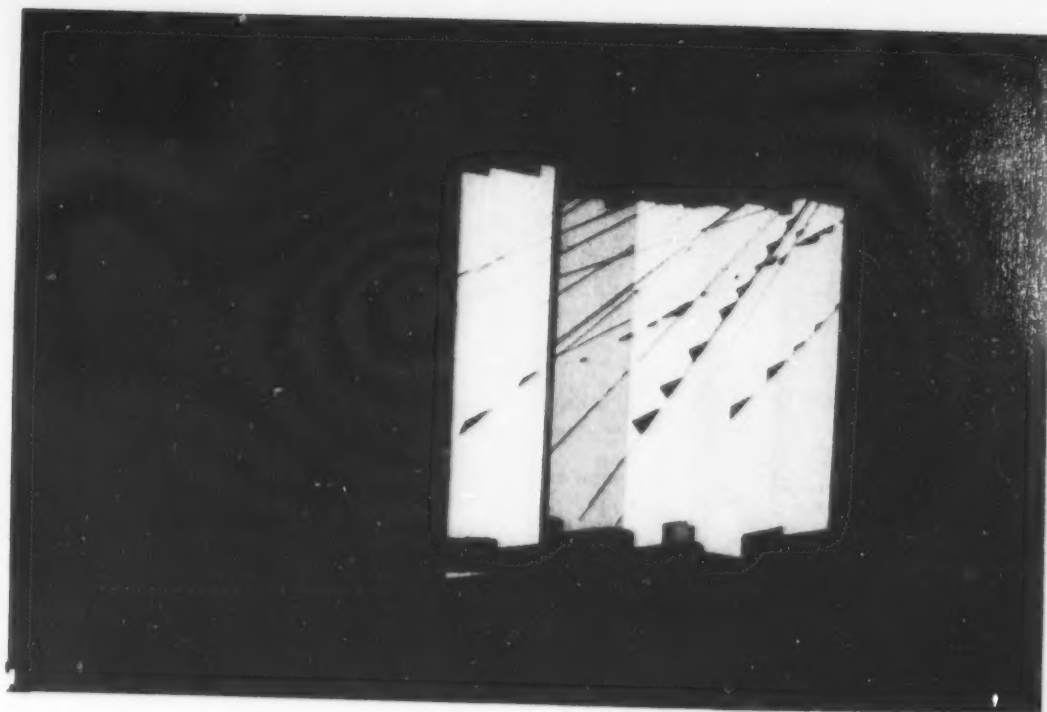


Figure 5-34 3-D South-E View - Axial Displacements - 4501 Panel

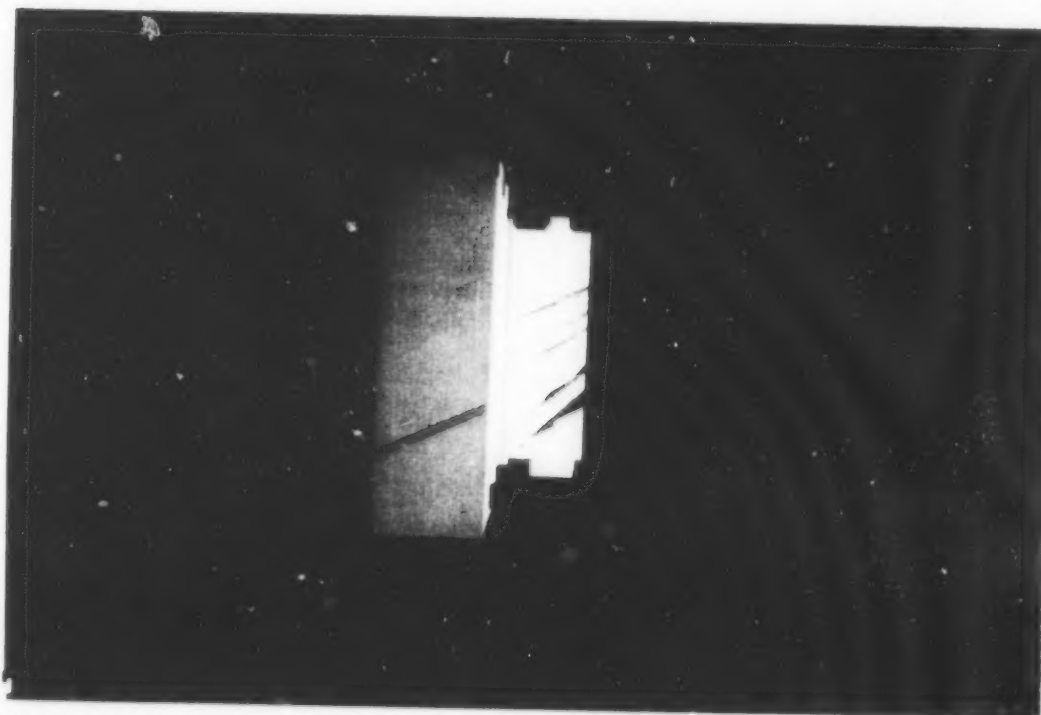


Figure 5-35 3-D East View - Axial Displacements - 4501 Panel

This is reflected in the inclinometer data for the horizontal displacement in this same hole. Negative horizontal displacements of 2 to 4 mm were measured during the mining of 4501 panel but are thought to be the result of movement along this major fracture initiated by the seventh cut development mining rather than the mining of the fourth panel.

The mining of 4501 panel caused localized displacement around the panel but little movement in the footwall section of the monitoring site. This indicates that the stress relaxation associated with this mining was restricted to the immediate location of the panel as is shown by the hatched lines in Figure 5-36.

5.5.2 Stress Measurements

Following the mining of 4501 panel two C.S.I.R.O. stress cells were overcored at a site in the footwall on 6600 level. Both stress cells were successfully recovered but the strain results are suspect due to questionable bonding of the strain gauges to the hole wall. On close inspection of the dissected overcore large air bubbles were observed in the glue next to several of the gauges.

A third cell was installed at this site and left in place to monitor the stress changes associated with the subsequent mining. This cell was, unfortunately, found to produce unstable readings and is thought to have been poorly bonded and was abandoned.

A stress cell that was installed in the site 2 hangingwall location on 6600 level was monitored from Sept. 28 to Dec. 17/88. The strain readings obtained from the 12 strain gauges did not show any appreciable stress change at this location as a result of the mining of 4501 panel. The data, however, is thought to be unreliable due to problems with the logging equipment used in the monitoring. It is unsure as to whether the logger was receiving a proper signal from all the gauges throughout the monitoring period.

This cell's cable was later damaged while trying to remove a vibrating wire stress ring which was installed in the same hole. The cell, therefore, could not be monitored during overcoring to confirm these suspicions.

5.6 4463 and 4465 V.R.M. Panel Mining (Mining Stage Six)

The mining of panel 4463 started on Jan. 13/89 but was suspended on Feb. 20/89 due to problems with the blasting. The burden between the holes was excessive which required the panel to be re-drilled. Approximately 26 meters of ground remained while the I.T.H. holes were redrilled. To offset the production loss, panel 4465 was mined ahead of schedule between March 3/89 and April 7/89.

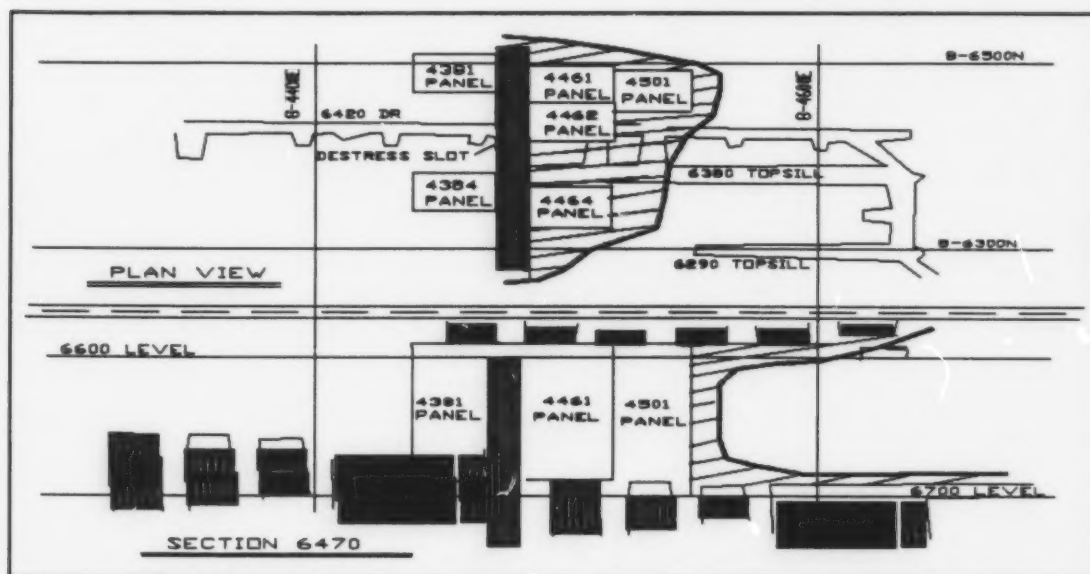


Figure 5-36 Stress Relaxation Zone Location - 4501 Panel Mining

There was insufficient time between the suspension of blasting in 4463 panel and the commencement of mining of 4465 panel to read all the instrumentation installed in the 4500 monitoring site. Consequently, the mining of the first half of 4463 panel and all of 4465 panel has been defined as one monitoring period (Figure 5-37). The third panel on the 4300 side of the destress slot was mined during this period of time.

The M.C.F. crown between 7000 and 6800 was still mined to 27 meters below 6800 level and had not shown any signs of high stress. It is assumed that this crown must have failed when the 4300 M.C.F. crown failed in October 1988. The area was converted to V.R.M. mining shortly after the 4465 panel mining was completed.

5.6.1 Displacement

The mining of the first half of 4463 panel and then the subsequent mining of 4465 panel cause varied rock mass displacements in the monitoring site (Figures 5-38 to 5-40). The mining caused virtually no axial displacements in the top hole (Figure 5-4) drilled on 6385 Section (hole 75422) and 0.5 to 3.0 mm in the lower vertical hole (75424 hole) which are both located directly in front of 4463 panel. The direction of displacement was away from the borehole collar and towards the mining. The largest displacements measured in the lower part of vertical hole are thought to be associated with the seventh cut mining on 6700 level.

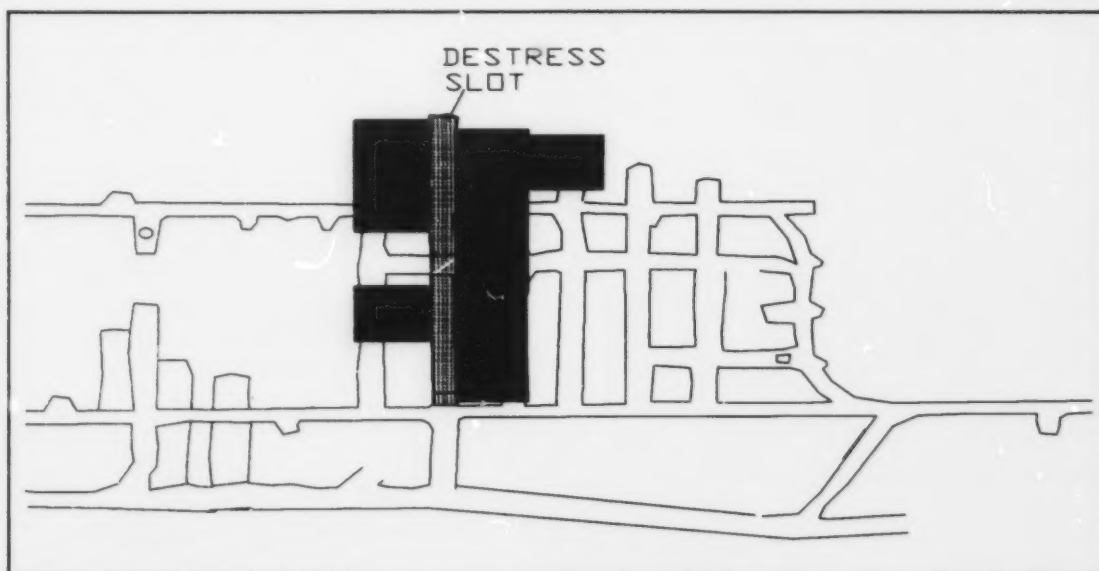


Figure 5-37 6600 Level Plan - 4465 & Half 4463 Panel Mining

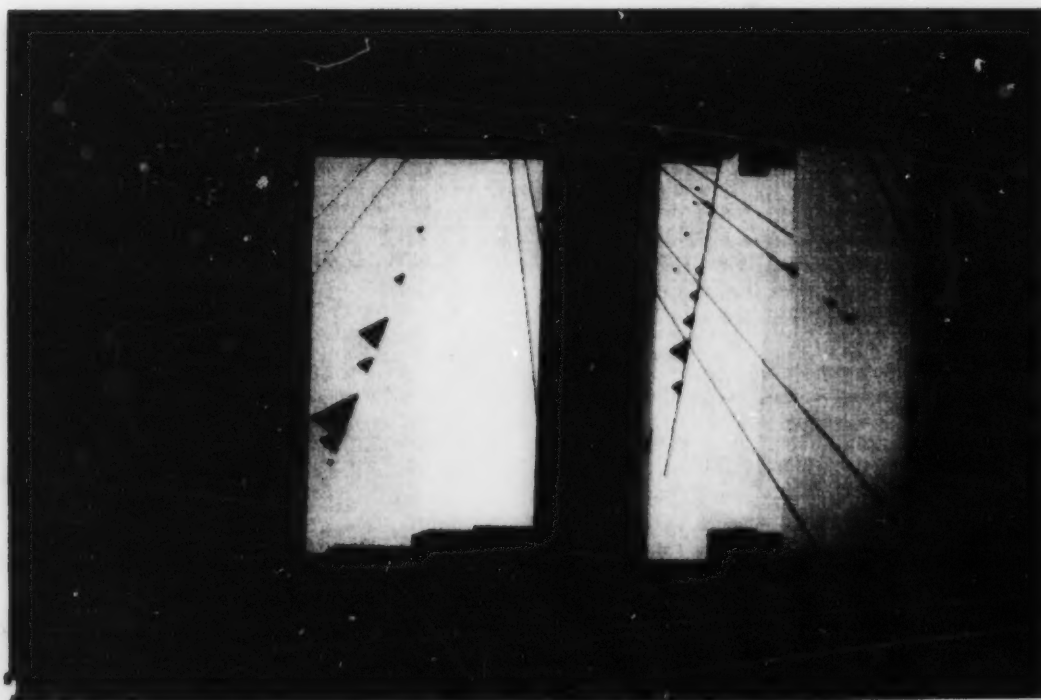


Figure 5-38 3-D South View - Axial Displacements - 4465/4463 Panel

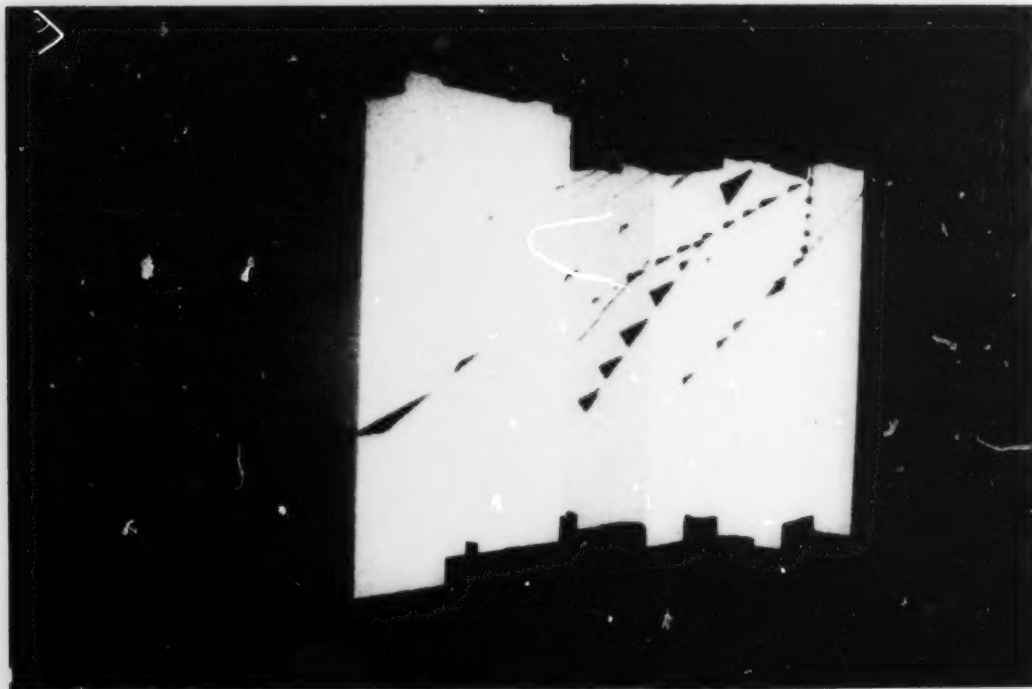


Figure 5-39 3-D South-E View - Axial Displacements - 4465/63 Panel

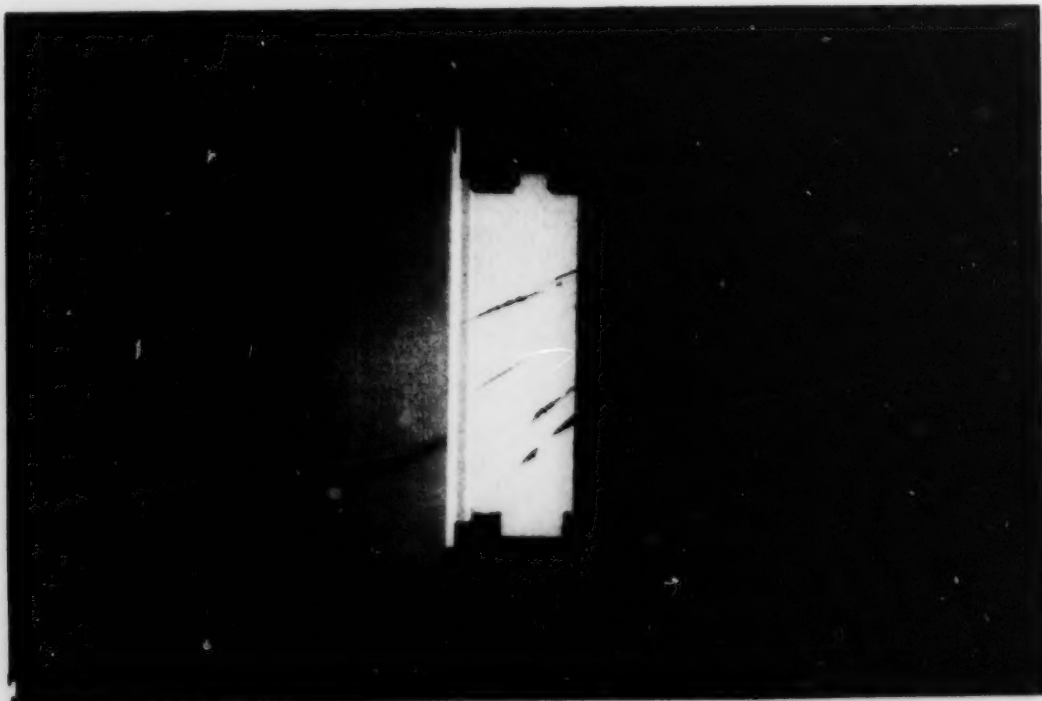


Figure 5-40 3-D East View - Axial Displacements - 4465/4463 Panel

The extensometer monitoring hole in Ring 1 (hole 75427) showed initial axial movement of 0.5 mm. away from the hole collar at most of its anchor points during the mining of 4463 panel then a reversal of direction of the movement towards the collar of 1.0 to 2.0 mm during the mining of 4465 panel. Considering the orientation of the hole, (Figure 5-4) which was drilled from 6340 drill station towards 4463 panel and away from 4465 panel, this change in displacement direction is understandable.

The major anchor movement measured during this stage of the mining was in the upper extensometer monitoring hole drilled in Ring 2 (hole 75431) which showed axial displacements away from the borehole collar of from 1.0 to 4.0 mm in the upper section of the hole and 2.5 to 7.0 mm displacements in the lower section. The second extensometer monitoring hole in this same ring (hole 75431) showed axial displacements of 0.5 to 1.0 mm occurring during the mining of 4463 panel and small displacements towards the collar during the mining of 4465 panel.

Axial displacement of 0.5 to 1.5 mm away from the collar in extensometer hole in Ring 4 (hole 75438) occurred mainly during the mining of 4465 panel. The anchor located at the 42 meter depth in this hole displaced 9 mm. This again can be explained by the movement of a small block, partially defined by one of the major fractures, that was showing movement due to the 6700 level seventh cut development mining. A portion of this block later sloughed into 4464 panel peeling the draw point brow back 3 meters. This block continued to show movement at this anchor point throughout the remainder of the monitoring period.

The anchor displacements in the Ring 4 hole (75441 hole) were again small and quite erratic with the exception of the 12 and 15 meter anchors which showed axial movements of 2.5 mm away from the borehole collar.

The erratic behaviour in the deeper rods may be attributed to them being pinched by the shear movement along some structure located past the 15 meter depth in this hole. This would constrict the movement of the rod anchors preventing them from accurately representing the axial displacement in the section of the rock mass in which they are located. The anchors below the 15 meter depth continued to perform erratically throughout the remainder of the monitoring project which led to them being excluded from the analysis of the displacement data.

The inclinometer readings did indicate some directional movement in several of the holes. The inclinometer showed ground movement in the lower monitoring hole drilled on 6385 Section (hole 75424) in a negative vertical direction to the axis of the hole. The upper hole in Ring 2 (hole 75431) showed positive vertical displacement at various depths along its length and negative horizontal displacement at the 30 meter depth only.

The lower hole (75432 hole) in that ring showed displacement in the positive vertical direction at the deeper anchors points. Negative horizontal displacement was measured in most of the lower part of the inclinometer monitoring hole in Ring 4 (hole 75438). The toe of this hole showed a positive displacement.

The mining of these two panels caused less displacement in the hangingwall section of the monitoring site than previous mining. It did increase the displacement in the footwall section due to the 4465 panel mining and caused some stress relaxation in this area (Figure 5-50).

5.6.2 Stress Measurements

A C.S.I.R.O. stress cell was installed across from the destress slot in the footwall on 6600 level and monitored from Jan. 7 to June 10/89. The strain readings from the cell indicate that most of the 12 strain gauges were not producing meaningful readings. The cell was either damaged or improperly installed in the hole.

Shortly after the completion of the mining in 4463 and 4465 panel another C.S.I.R.O. was installed and overcored in the hangingwall at site 2 on 6600 level. The overcoring, unfortunately, was not successful due to the de-bonding of several of the cell gauges. It was at this stage of the rock mass monitoring project that it was decided to abandon the stress measurement program of overcoring because of the difficulty that was experienced in finding suitable ground in which to install the cell and the poor success rate when overcoring.

An alternative program of stress monitoring was initiated as indicated in Section 4.0. The location of the successfully installed monitoring cells are shown in Figures 5-41, 5-42 and 5-43.

5.6.3 Borehole Logging During 4465 Panel Mining

The inspection boreholes on 6600 level were logged with a television camera for the third time in the project during the mining of 4465 panel. Unfortunately, time allowed only the television camera monitoring holes (Figure 5-4) drilled from 6340 drill station on 6600 level to be logged. The holes drilled in the hangingwall and the footwall and the hole drilled on Sections 6400 and 6385 (holes 75420, 75421 and 75423) were not inspected until later in the project. A 3-D representation of the visual observations made in the holes that were logged is given in Figures 5-44 to 5-49. The only area that showed any substantial increase in highly fractured ground from the previous logging was just above 6700 level in the area that was being developed at the seventh cut elevation.

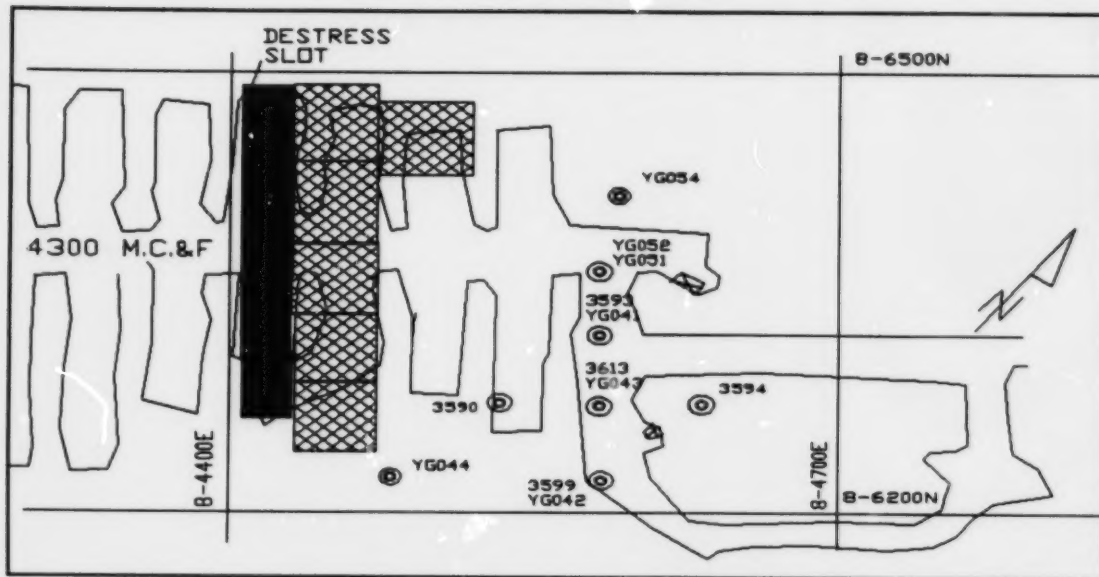


Figure 5-41 6700 Level Plan - HI & Yoke Stress Cell Locations

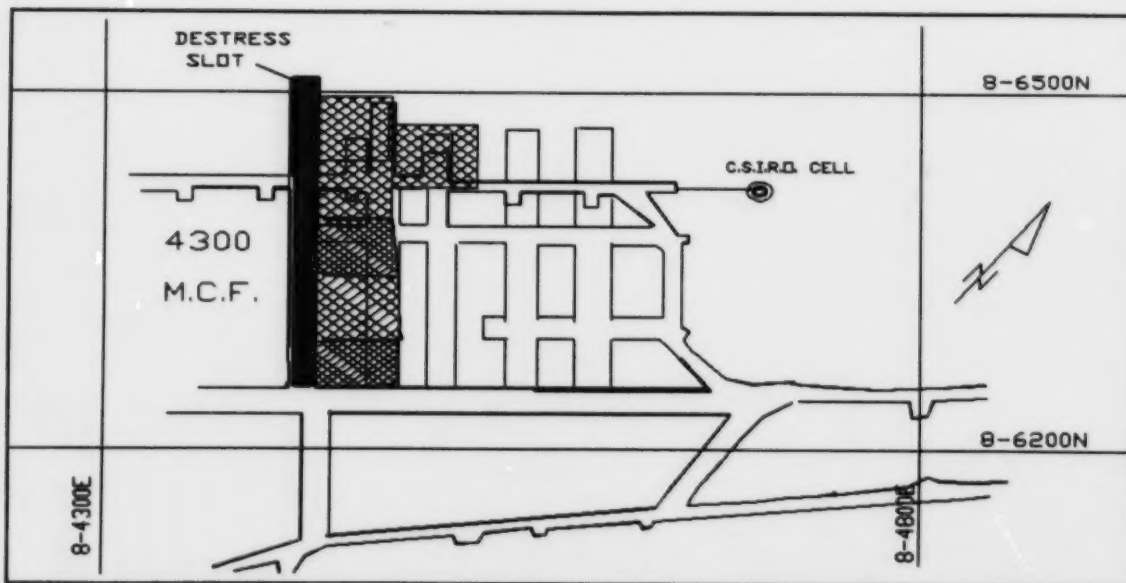


Figure 5-42 6600 Level Plan - HI Stress Cell Location

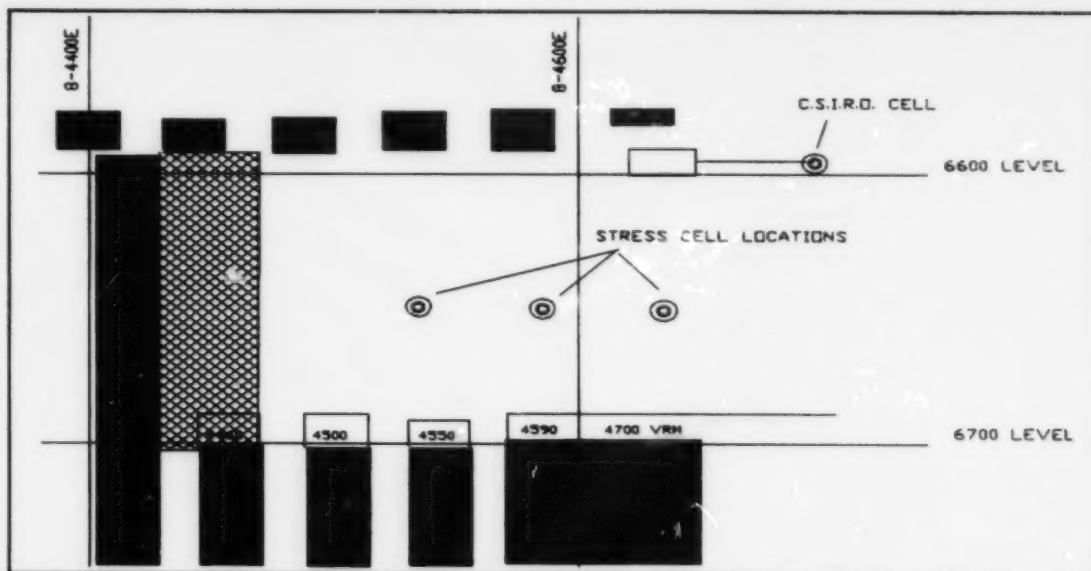


Figure 5-43 Section of Mining Block - Stress Cell Locations

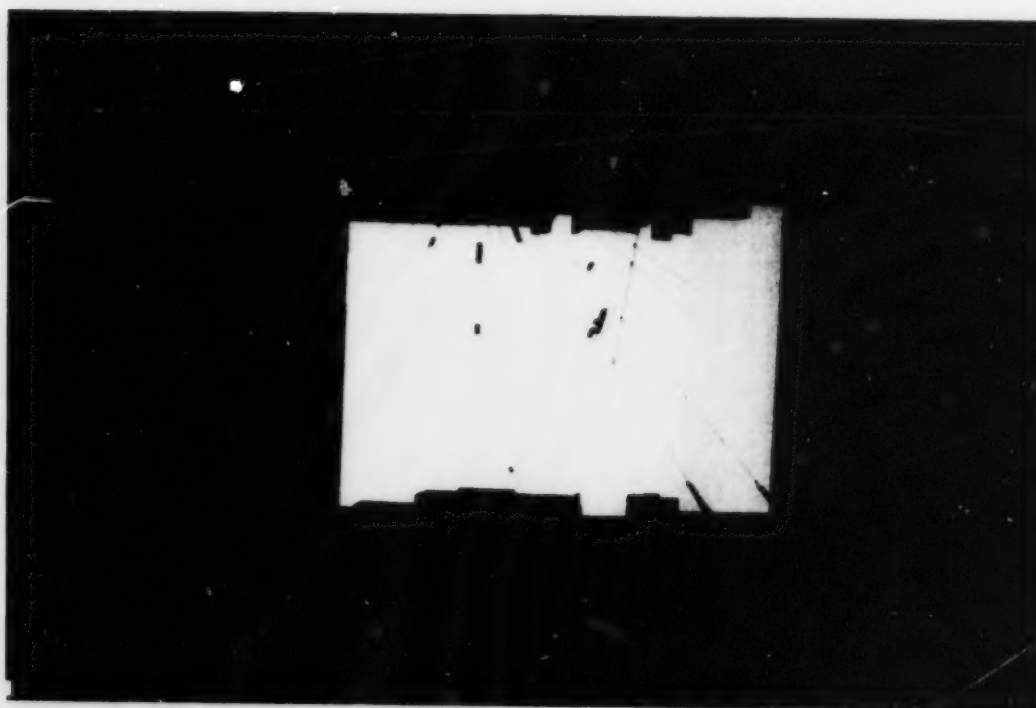


Figure 5-44 3-D South View - Highly Fracture Zones - 4465/63 Panel

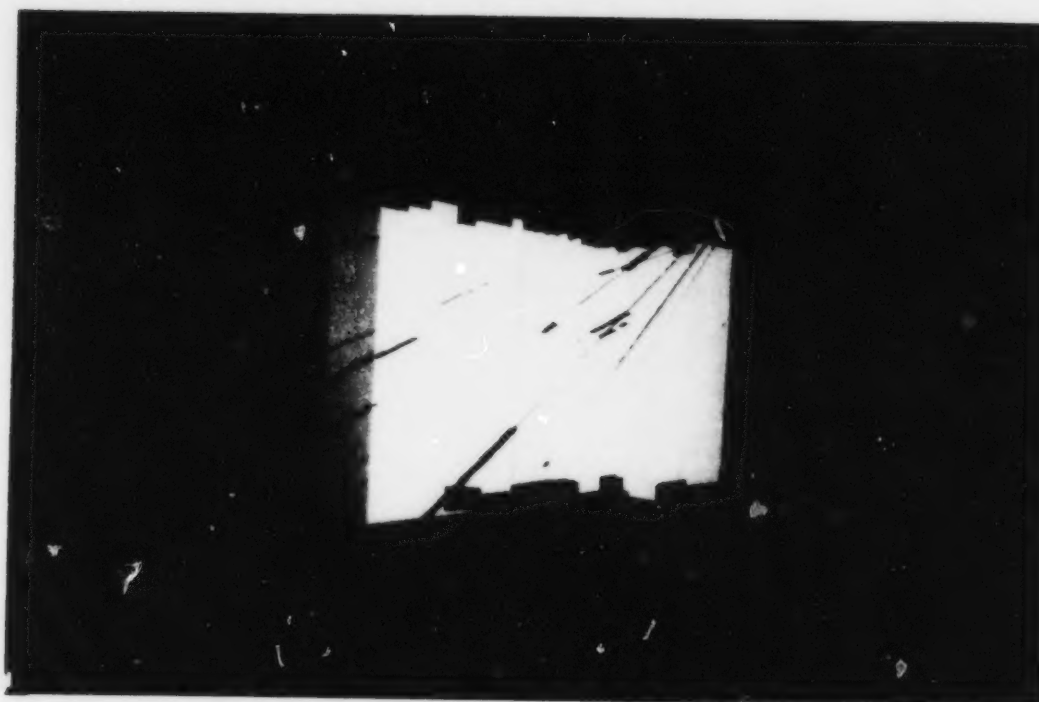


Figure 5-45 3-D S-E View - Highly Fracture Zones - 4465/63 Panel

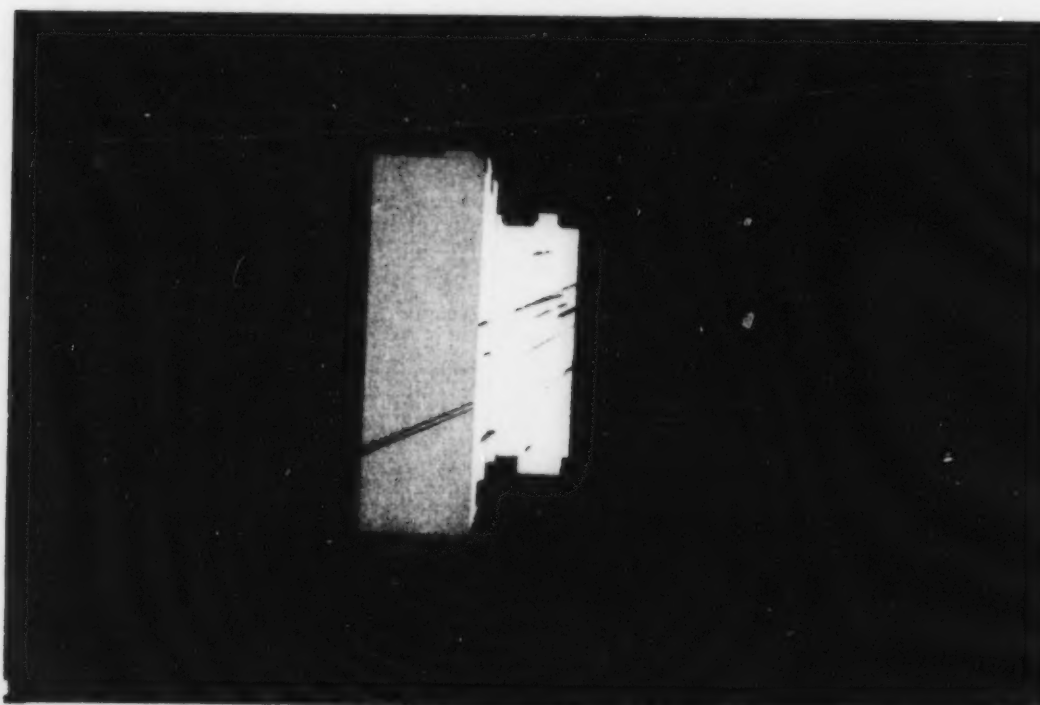


Figure 5-46 3-D East View - Highly Fracture Zones - 4465/63 Panel

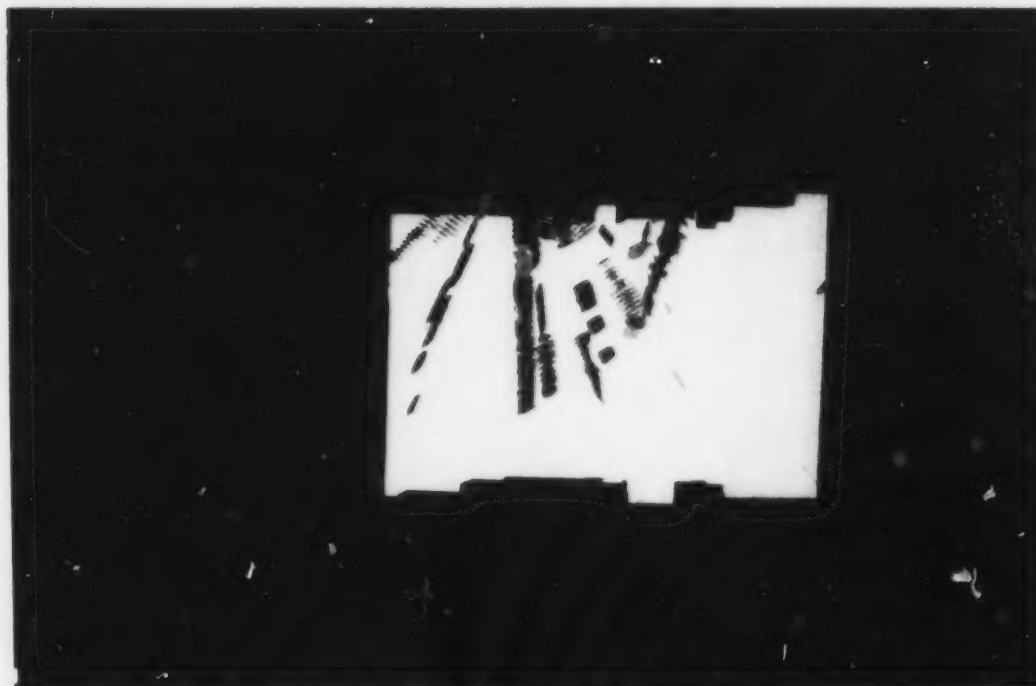


Figure 5-47 3-D South View - Borehole Spalling - 4465/43 Panel



Figure 5-48 3-D South-E View - Borehole Spalling - 4465/43 Panel

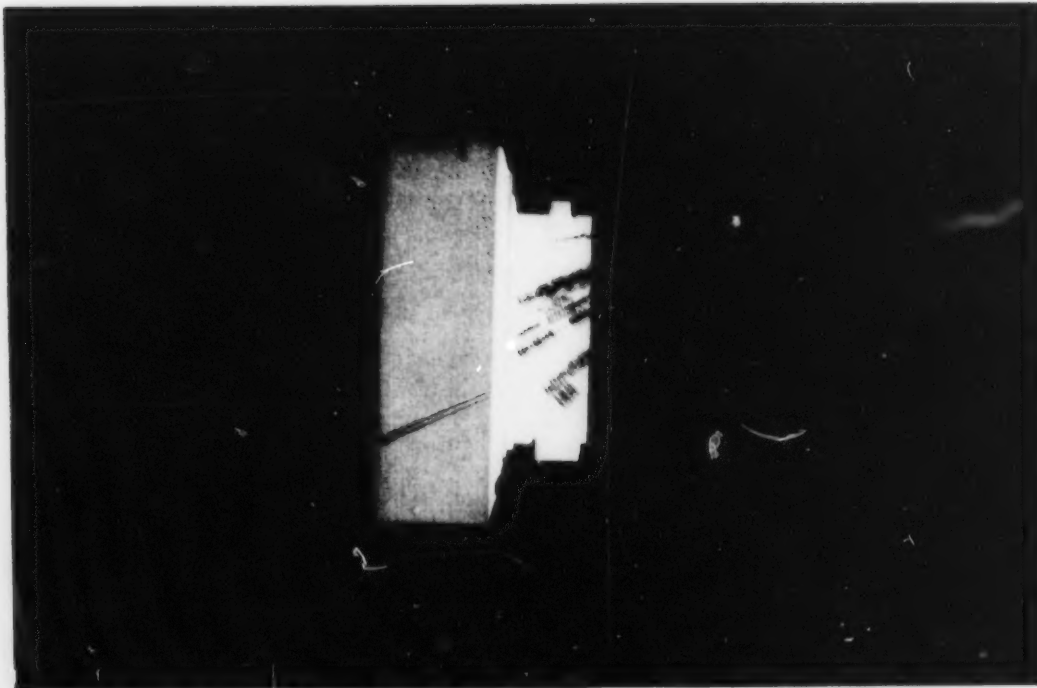


Figure 5-49 3-D East View - Borehole Spalling - 4465/43 Panel

This increase in fractured ground was likely the result of the development mining rather than the mining of the V.R.M. panels.

The logging did show a substantial increase in the spalling in many of the boreholes. The increased spalling directly in front of 4463 panel and adjacent to 4501 panel suggests that this area was still highly stressed and therefore outside of the stress relaxation zone before 4501 panel was mined. This agrees with the interpretation of the relaxation zone migration at that stage of mining shown by the hatched lines in Figure 5-31.

The boreholes closer in the footwall and in front of 4465 panel all showed increased areas of spalled ground which demonstrate that this area was outside the relaxation zone prior to the 4465 panel mining, which agrees with the relaxation zone location shown by the hatching in Figure 5-36.

Based on the visual observations made during the logging of these hole and the displacements measured in the different area of the monitoring site an estimate of the location of the stress relaxation zone at this stage of the mining was made as shown in Figure 5-50.

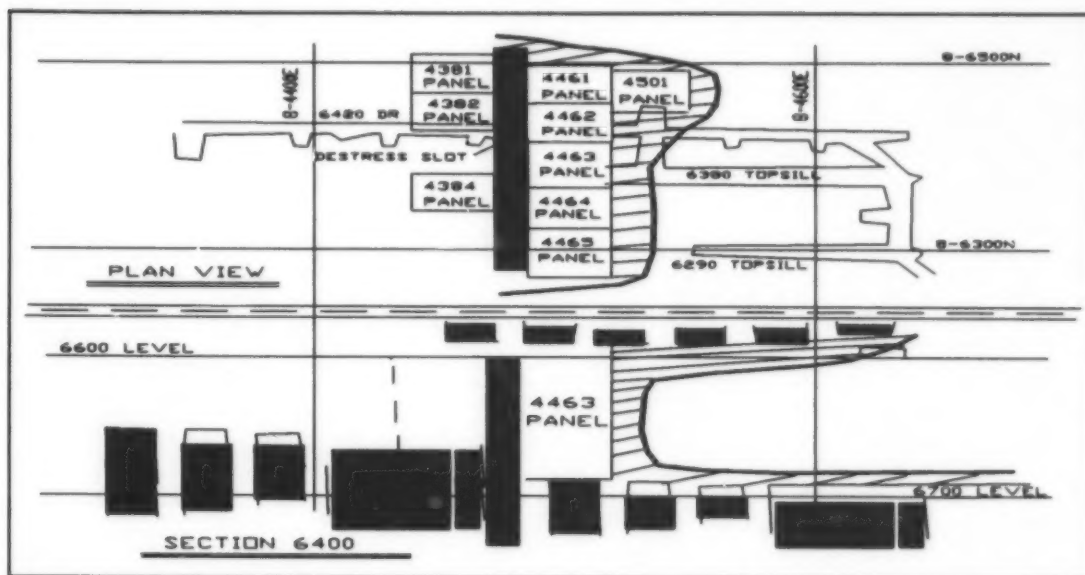


Figure 5-50 Stress Relaxation Zone Location - 4465/63 Panel Mining

5.7 The Second Half of V.R.M. Panel 4463 Mining

The re-drilling of the blasting holes in the second half of panel 4463 was completed in May/89. The remaining mining in the panel was conducted between June 5 and Aug. 1/89. This time period included a one month vacation shutdown in July during which no mining took place at Creighton Mine.

There was one further V.R.M. panel excavated on the 4300 side of the destress slot and the first panel mined in 7000 and 6800 M.C.F. crown before the resumption of mining in 4463 panel (Figure 5-51)

The 6700 level drilling of the holes in which to install the stress cells for stress monitoring continued during this period. No stress data was collected during this mining period.

5.7.1 Displacement

The axial displacements associated with mining of the second half of 4463 panel were minor (Figures 5-52 to 5-54). The only displacements thought to be associated directly with this half of

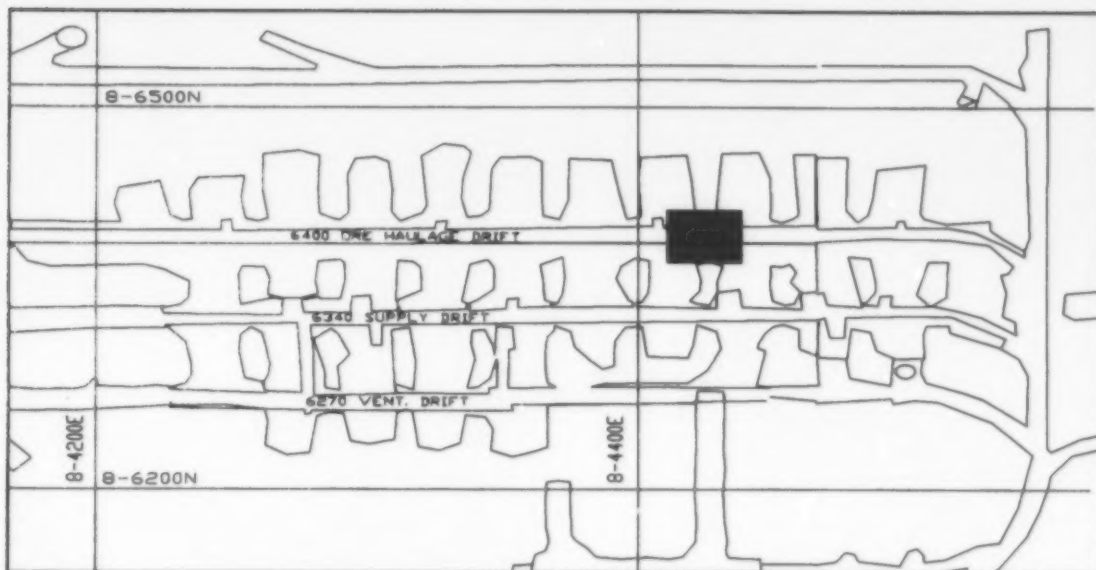


Figure 5-51 6800 Level Plan - First Panel Mining - 7000 Crown

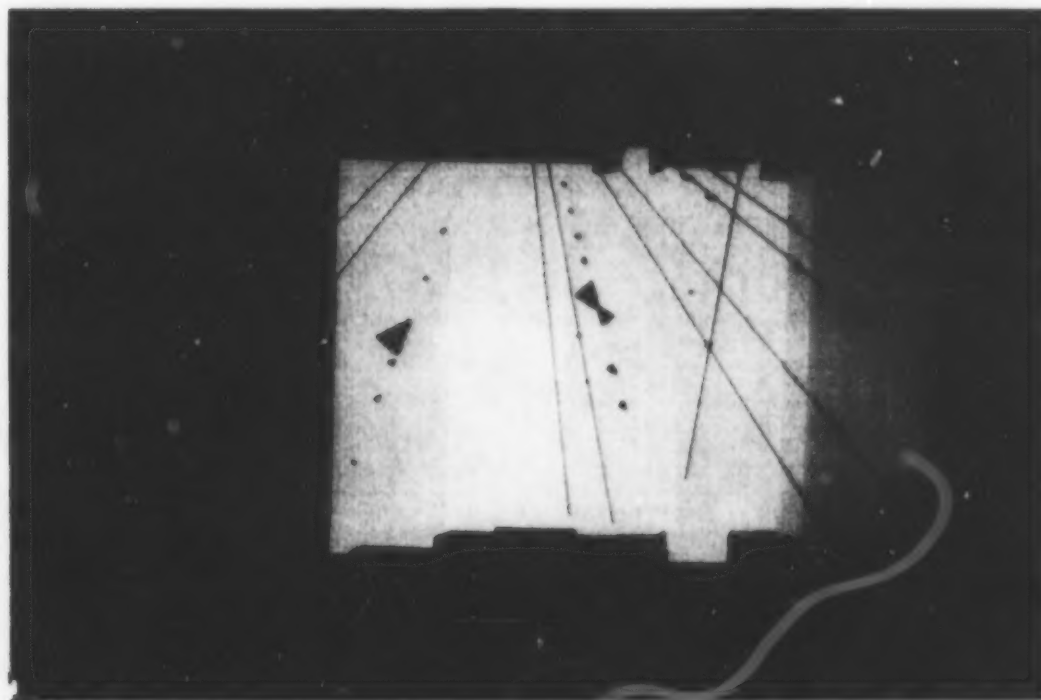


Figure 5-52 3-D South View - Axial Displacements - Half 4463 Panel

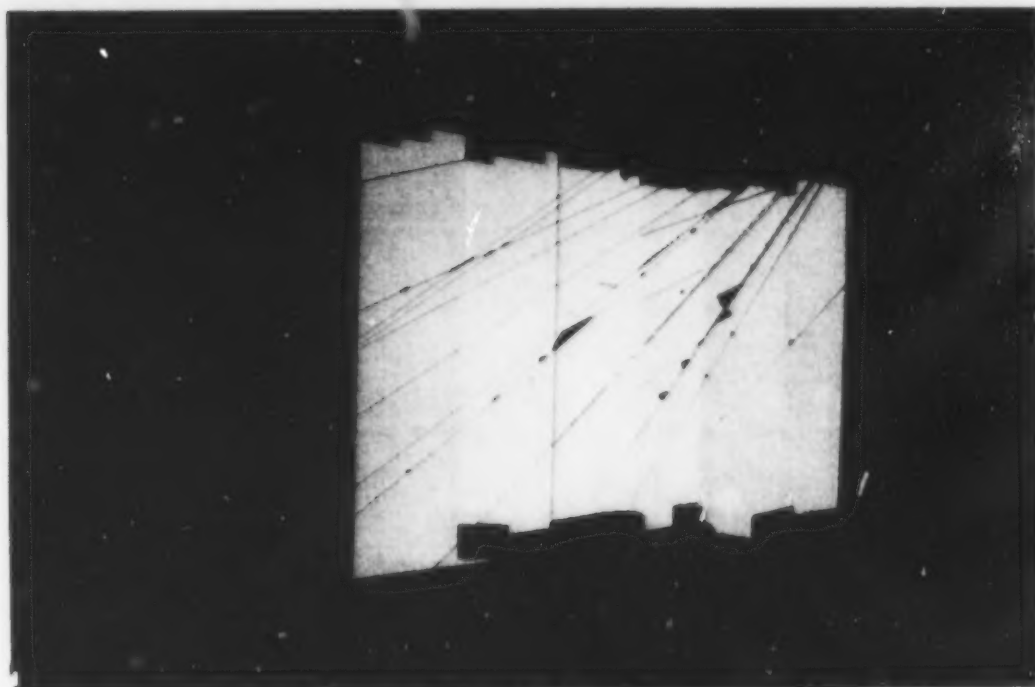


Figure 5-53 3-D S-E View - Axial Displacements - Half 4463 Panel

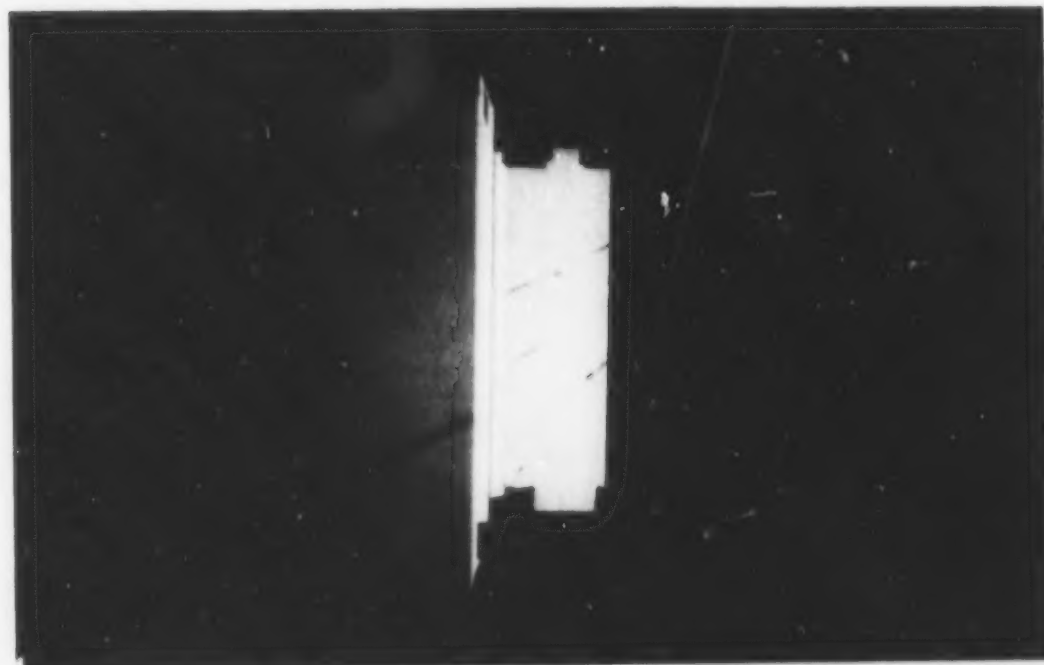


Figure 5-54 3-D East View - Axial Displacements - Half 4463 Panel

the panel mining (Figure 5-4) appear to be in Ring 1 extensometer hole (i.e. 75427 hole) which showed axial movement of 1.0 to 1.5 mm away from the hole collar. The movement was greater in the upper anchors than in the lower anchors; the lower anchors are located in the hangingwall, away from mining in 4463 panel mining.

There was movement measured in the monitoring holes drilled on Rings 2 and 4 (holes 75431 and 75438) during this mining period but this axial displacement is thought to be the result of the further block movement resulting from the drift development mining at the seventh cut elevation on 6700 level. These two holes, 75431 and 75438, are located directly in this area of known block movement. The inclinometer readings, in general, again provided poor data on the ground movement associated with the progressive mining. The readings from one hole, however, did show major movement in the rock mass after the mining of 4465 panel and before the mining of the second half of 4463 began.

The inclinometer readings from the monitoring hole drilled in Ring 4 (hole 75438) show a displacement in the negative horizontal direction to the axis of the hole of 90 to 100 mm in the upper section of the hole. The magnitude of the displacement decreases with depth eventually showing a positive horizontal movement in the lower section. The magnitude of these horizontal displacements in this hole were large in comparison to the vertical and axial displacements measured for this same period.

No displacements of similar magnitude were measured in any of the other monitoring holes during the mining of this or any other panel in the monitoring site. The subsequent consistency of the displacement leads us to conclude that the data is realistic and that a major block movement took place at this stage of mining.

No attempt will be made in this report to define the block definition and failure sequence that made up this event. The purpose of the field monitoring program was to collect data to calibrate a continuum boundary element code which can not simulate this type of failure. Consequently, the definition of the failure sequence associated with this measured displacement are thought to be beyond the scope of this field study and will be saved for future analysis.

The small displacements associated with the mining of the second half of the panel indicate that it was within the relaxation zone during its final excavation as indicated in Figure 5-50.

5.8 4551 V.R.M. Panel Mining

The mining of 4551 panel (Figure 5-55) took place between Aug. 25 and Oct. 27/89. Two further V.R.M panels were mined on the 4300 side of the distress slot and the second panel in the 7000 to 6800

level crown (Figure 5-56).

The drilling of the 6700 level holes for stress monitoring was continuing and the installation of two of the cells was completed in time to monitor the end of mining in this panel.

During the drilling of 4551 panel the 51 meter extensometer rods in the monitoring hole drilled in Ring 1 (hole 75427) were intersected by the I.T.H. drill and destroyed. Later in the mining of this same panel the 48 meter rod was destroyed by the blasting.

5.8.1 Displacement

The majority of the axial displacement measured during the 4551 panel mining was concentrated in an area adjacent to the excavation. Displacements of 2.2 to 5.5 mm were measured in the extensometer monitoring hole (Figure 5-4) drilled on Section 6385 and in Ring 1 (holes 75422, 75424 and 75427). The upper monitoring hole in Ring 2 (hole 75431) showed axial displacements of 10 to 13 mm in the anchors 30 meter and longer. This movement, because it is not reflected in the upper hole anchors, is thought to be

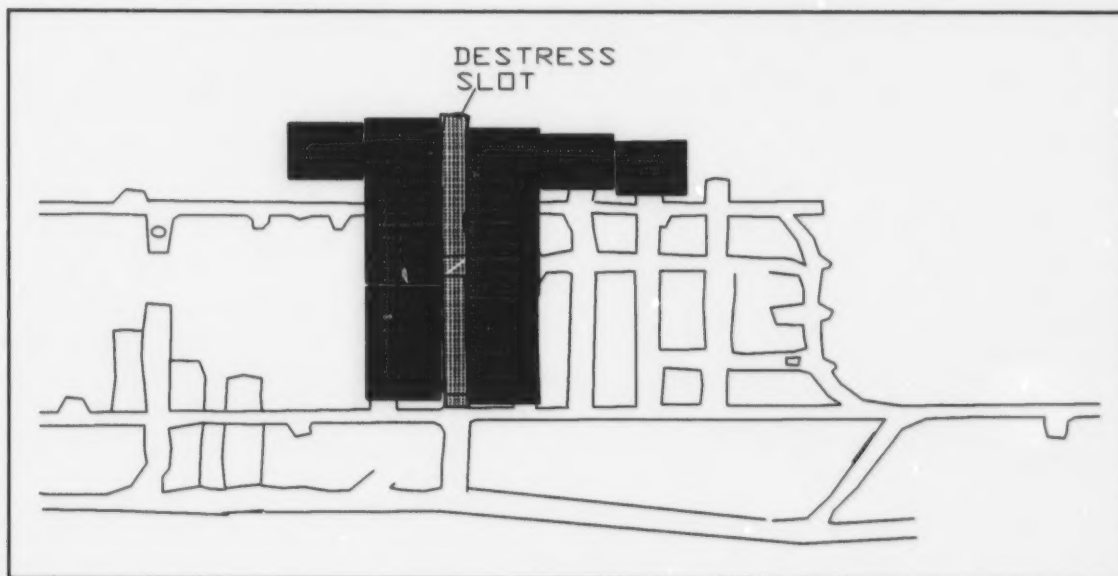


Figure 5-55 6600 Level Plan - 4551 Panel Mining

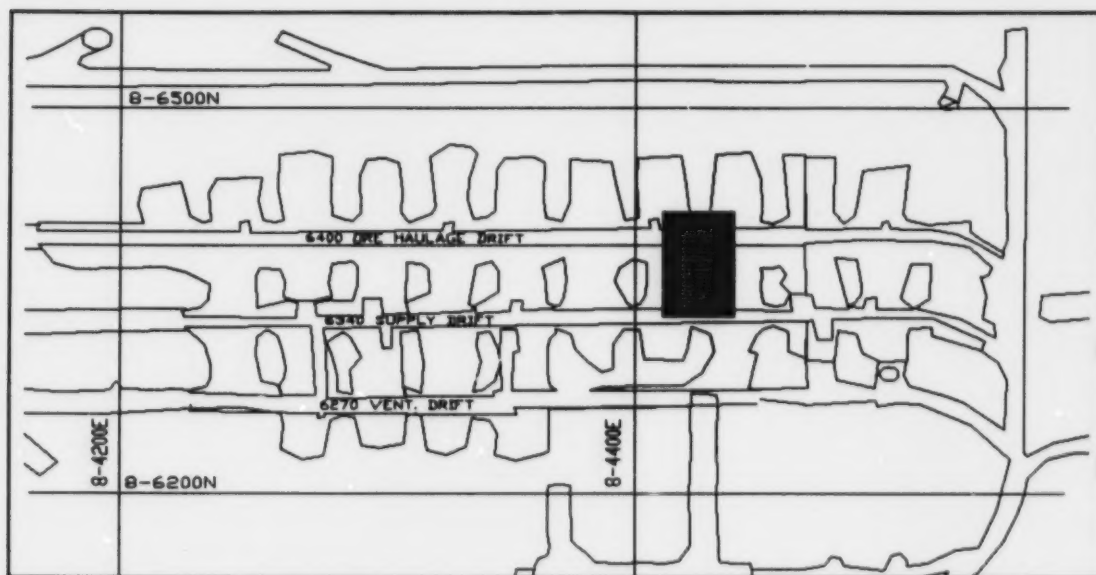


Figure 5-56 6800 Level Plan - Second Panel Mining - 7000 Crown

associated with a block structure at this depth that was mobilized at this stage of the mining. The rock mass movement measured in the holes closer to the footwall was less in magnitude at 0.5 to 1.0 mm.

The axial displacements measured over this time period may not have been attributed entirely to the mining of 4551 panel. The first half of 4504 panel was being mined over the same time period. Panel 4504 is located closer to the footwall in the area that showed the least axial ground movement during this period. The partial mining of this panel could have contributed to a small extent to the area's displacement.

The only inclinometer data that appeared to be meaningful again came from the monitoring hole in Ring 4 (hole 75438) which showed a continued negative horizontal displacement along the entire length of the hole. The lower section of the hole showed positive vertical displacement.

5.8.2 Stress Monitoring

The triaxial C.S.I.R.O. stress cell 3244 located in the hangingwall on 6600 level and cell 3591 located mid-height in the monitoring block were in place and monitored part way through the mining of 4551 panel. The strain changes monitored by cell 3591 did not show any meaningful stress change which was later found to be due to the defective bonding of the cell to the borehole wall. This

cell was later pulled out of the hole during the installation of a biaxial Yoke cell in the same hole.

Cell 3244 on 6600 level did not show any stress change until the crown blast in 4451 panel. As shown by the strain changes in Figure 5-57, the final removal of the crown in this panel caused the stresses at this point in the monitoring block to be redistributed. The first strain changes shown in Figure 5.57 were the result of the crown being removed. The second change 8 hours after the crown blast was the result of a 1.7 Richter magnitude rock burst that was located 15 meters below 6600 level directly below the 3244 cell. The subsequent smaller change in strain was caused by a 3.6 Richter rock burst which occurred in the footwall at the west end of the ore body, approximately 250 meters away from the cell location.

The three events caused stress at this point to increase by 0.41, 0.36 and 0.20 MPa. respectively. The magnitude and direction of the stress changes expressed as principle stresses can be found in the data files. These stress change measurements are too small to be used in the calibration of any existing numerical codes. The accurate calibration of small stress changes at any given point in the mining geometry that exists in the monitoring site is beyond

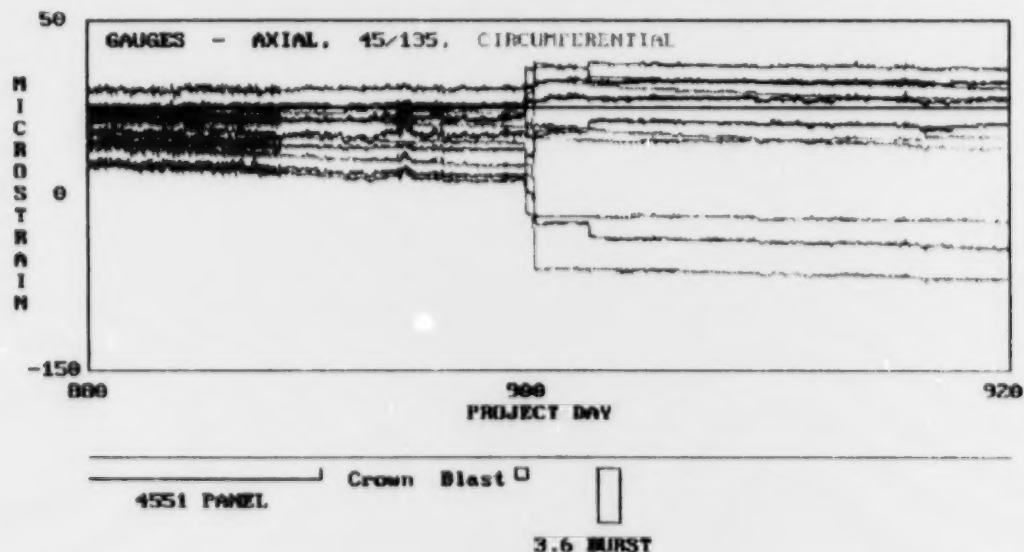


Figure 5-57 Strain Data From Cell 3244 - 4551 Panel Mining

the capabilities of present day numerical models. These stress change events are also associated with fault slip failures which cannot be simulated in the continuum boundary element code being created as part of this project.

The holes drilled to mine 4551 panel showed the holes closest to the previously mined 4501 panel showed no spalling while the holes approximately 7 meters from the wall of that panel were deeply spalled indicating the ground was highly stressed. The interface between the relaxation zone and the high stress area obviously ran through this panel which agrees with its estimated location shown by the hatched lines in Figure 5-36 and 5-50.

The mining of 4551 panel caused a large shift in the location of the stress relaxation zone. Advancing the mining by this one panel on the hangingwall produced a relatively large stress readjustment in this location which caused the only Richter size microseismic event in the monitoring site. The large displacements measured in the hangingwall section of the monitoring site and the stress changes measured with the crown blast indicate that a large portion of the rock mass underwent a relaxation of the field stresses which caused a minor fault-slip rock burst. This mining step caused the stress relaxation zone to migrate outward to the east past 4551 panel as shown by the hatched lines in Figure 5-58.

5.9 4504 V.R.M. Panel Mining

Panel 4504 was mined in two stages. The first stage, which resulted in approximately half the panel being excavated, took place between Sept. 19 and Oct. 25/89. Mining was halted at this time due to continued rock bursting in the 402 ore pass system which handled the ore from this mining location. The panel mining was not resumed until Dec. 22/89 and continued until Jan. 23/90 when the crown was blasted. Two V.R.M. panels on the 4300 side of the destress slot were completed during the initial stage of mining and a third was completed shortly after the completion of the second stage (Figure 5-59). One panel in the 7000 to 6800 crown was mined during the initial 4504 mining with a second being mined during the final excavation stage (Figure 5-60).

5.9.1 Displacement

The initial mining of panel 4504 was over the same time period as 4551 panel and may have contributed in a small way to the displacements measured adjacent to this hangingwall panel even though the displacements measured closer to 4504 panel were small. The second half of the mining in 4504 panel produced axial displacements in the monitoring holes of 0.5 to 1.5 mm (Figures 5-61 to 5-63) with the exception of the lower anchors (Figure 5-4) in the monitoring hole drilled in Ring 2 (75431 hole) which are

thought to be associated with block movement at this elevation. This was indicated by the lack of similar movement in the upper anchors in this same hole. The displacement data obtained with the inclinometer probe was again only meaningful in the monitoring hole in Ring 4 (hole 75438) with negative horizontal displacement in the upper part of the hole and positive horizontal displacement in the lower section of the hole.

5.9.2 Stress Monitoring

The triaxial stress cell 3244 in the hangingwall on 6600 level continued to be monitored during the entire mining of 4504 panel. Stress cell 3591 that was monitored during the mining of 4551 panel was disconnected from the logger on Nov. 15/89 and the newly installed cell 3594 was connected and monitored for the duration of the 4504 mining period. This cell was located mid height in the monitoring site and installed from 6700 level.

The strain change data from both cells did not show any indication of stress change at these two points that could be attributed to the mining of 4504 panel. The displacement and stress monitoring data indicate that the mining of this panel caused very little response by the rock mass which indicates it was within the stress relaxation zone. This confirms the previous estimation of the relaxation zone location shown in Figure 5-58 and suggests that the zone location changed little as the result of this panel mining.

5.10 4502 V.R.M. Panel Mining (Mining Stage Seven)

Mining in 4502 panel (Figure 5-64) was conducted between Mar. 8 and April 26/90. Three different panels on the 4300 side of the distress slot were mined during this period along with one panel in the 7000 to 6800 crown (Figure 5-65).

5.10.1 Displacement

The axial displacements associated with the mining of 4502 panel (Figure 5-66 to 5-68) were small ranging from 0.5 to 1.0 mm with the exception of the lower section of the top monitoring hole in Ring 2 (hole 75431). The anchors at the 30 to 42 meter depth in this hole displaced 2.0 to 3.0 mm which is again thought to be associated with a structurally defined block movement as previously indicated.

The extensometer rods anchored below the 30 meter depth in the top hole (Figure 5-4) drilled on 6385 Section (hole 75422) were intersected and destroyed during the mining of this panel. The initial mining caused axial displacement away from the borehole collars and then back towards the collars during the final mining

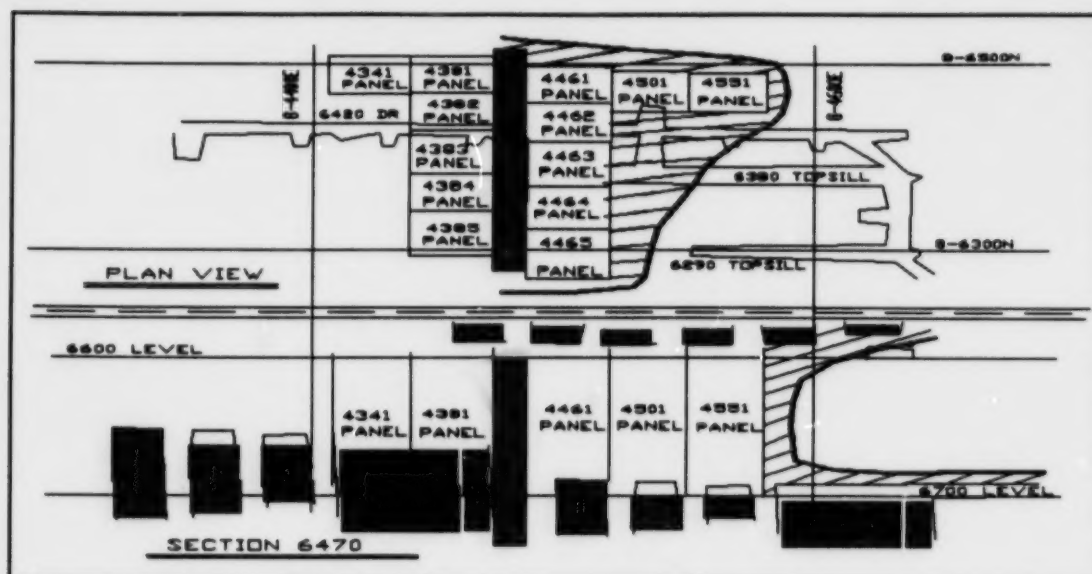


Figure 5-58 Stress Relaxation Zone Location - 4551 Panel Mining

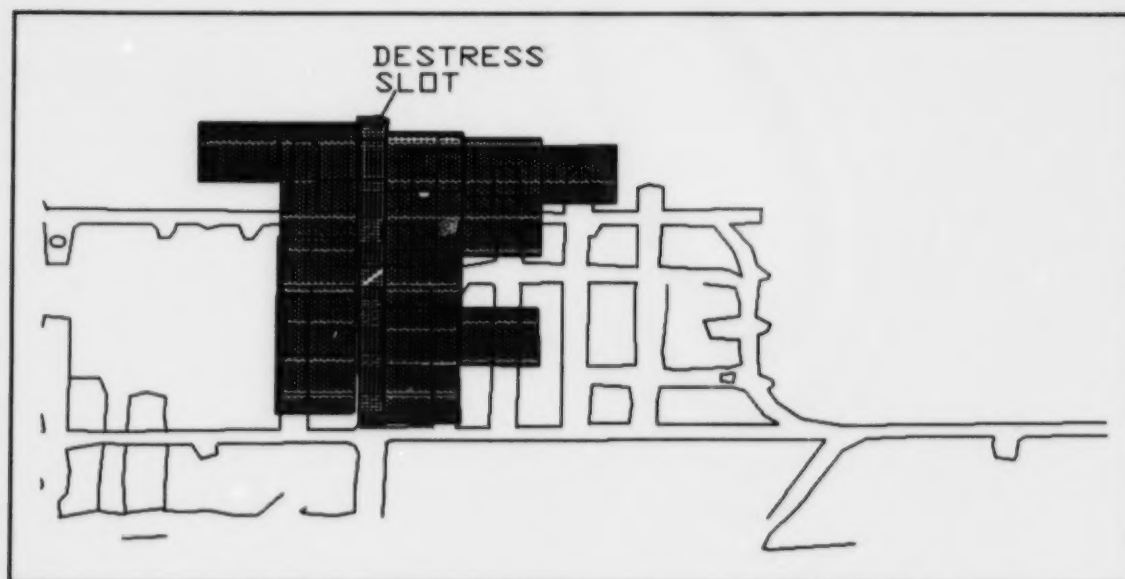


Figure 5-59 6600 Level Plan - 4504 Panel Mining

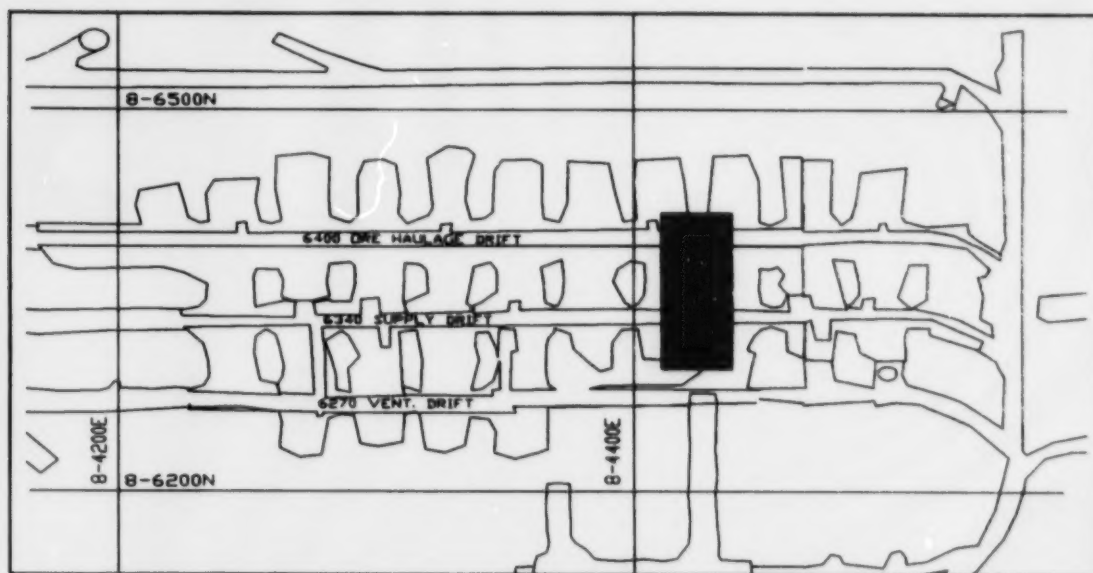


Figure 5-60 6800 Level Plan - Third Panel Mining - 7000 Crown

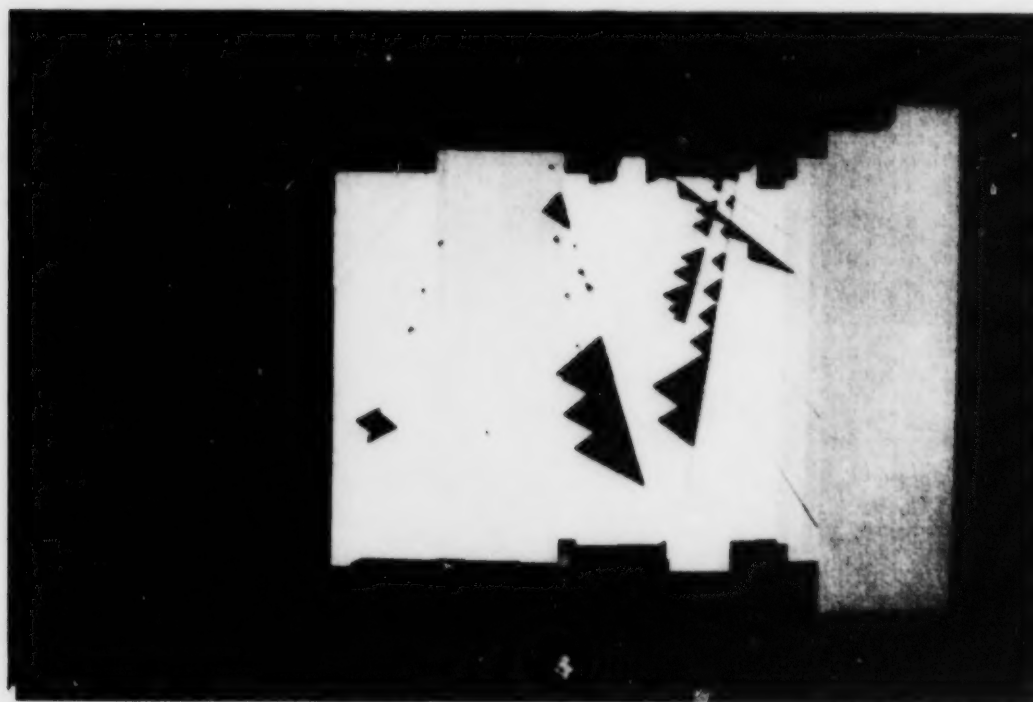


Figure 5-61 3-D South View - Axial Displacements - 4504 Panel

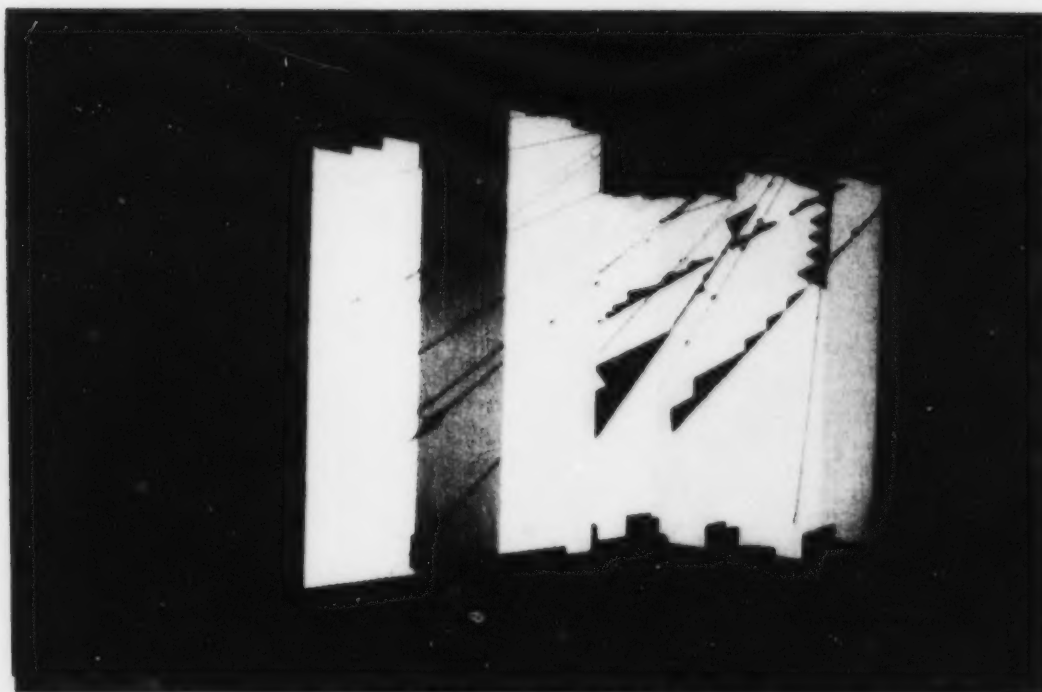


Figure 5-62 3-D South-E View - Axial Displacements - 4504 Panel

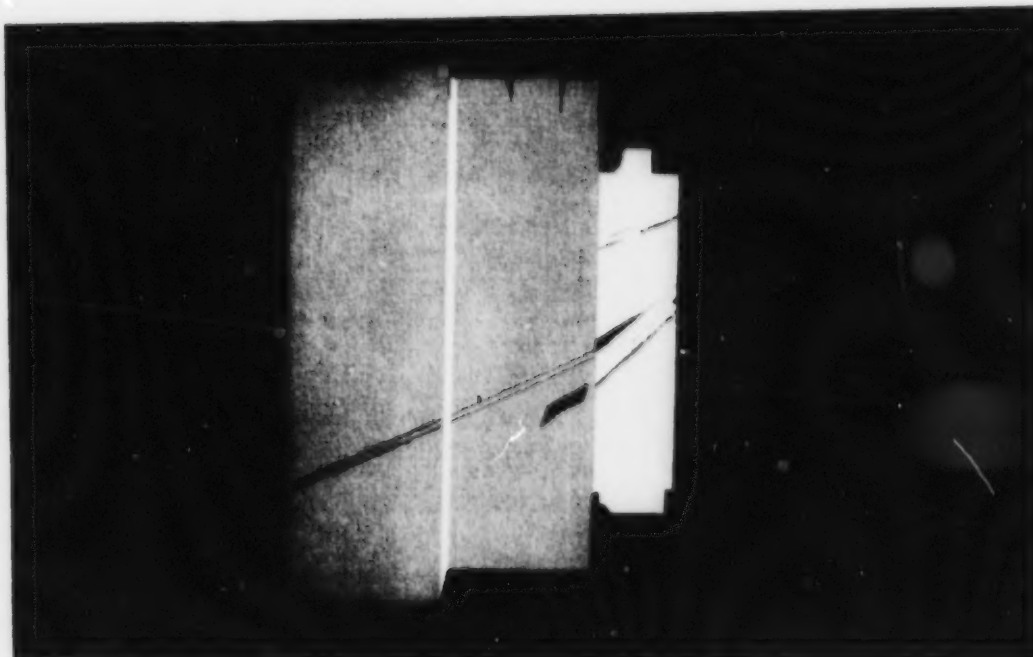


Figure 5-63 3-D East View - Axial Displacements - 4504 Panel

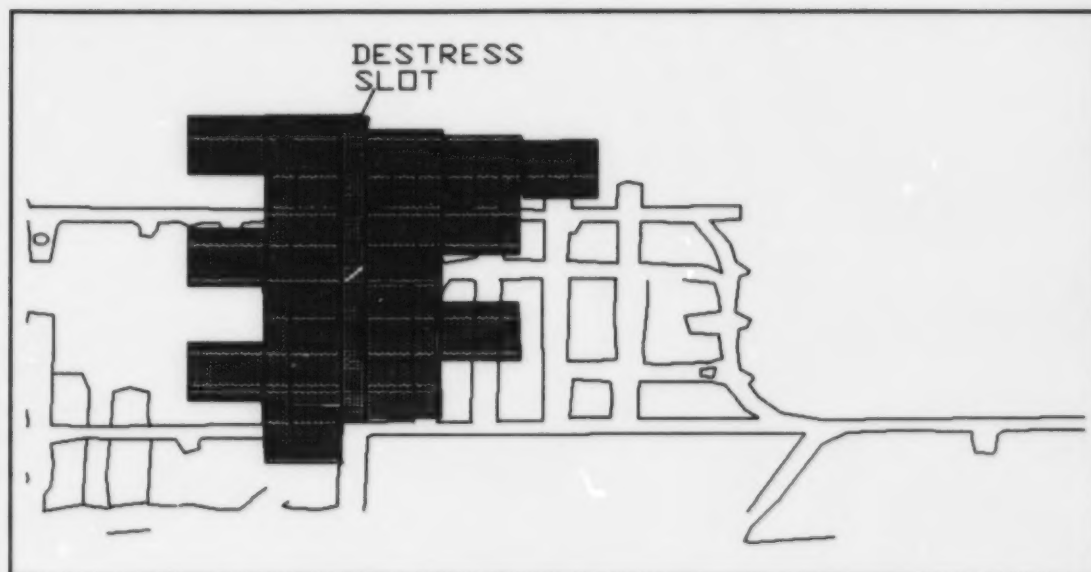


Figure 5-64 6600 Level Plan - 4502 Panel Mining

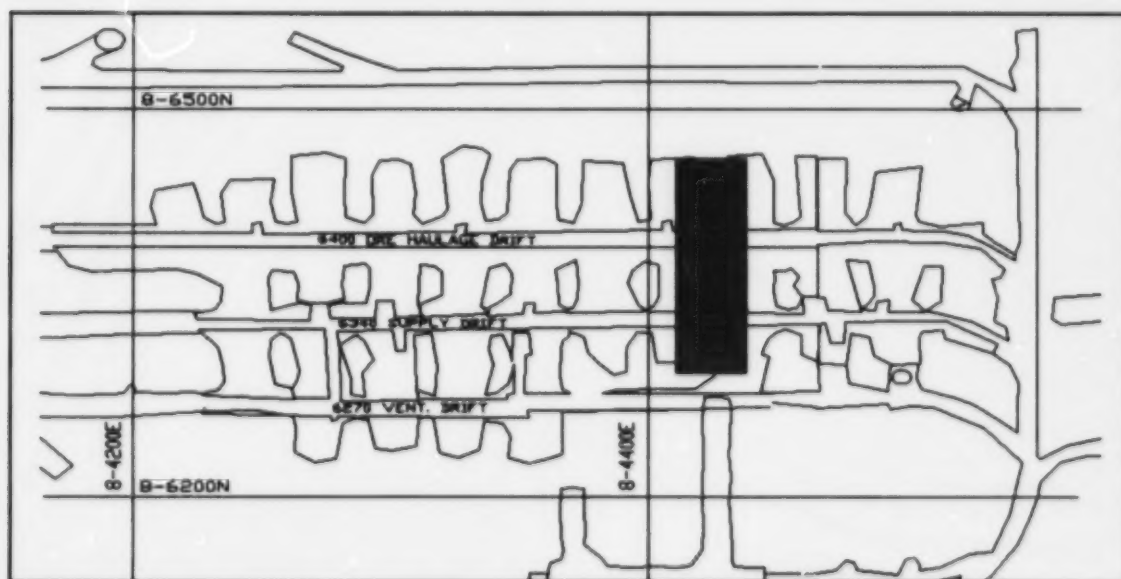


Figure 5-65 6800 Level Plan - Fourth Panel Mining - 7000 Crown

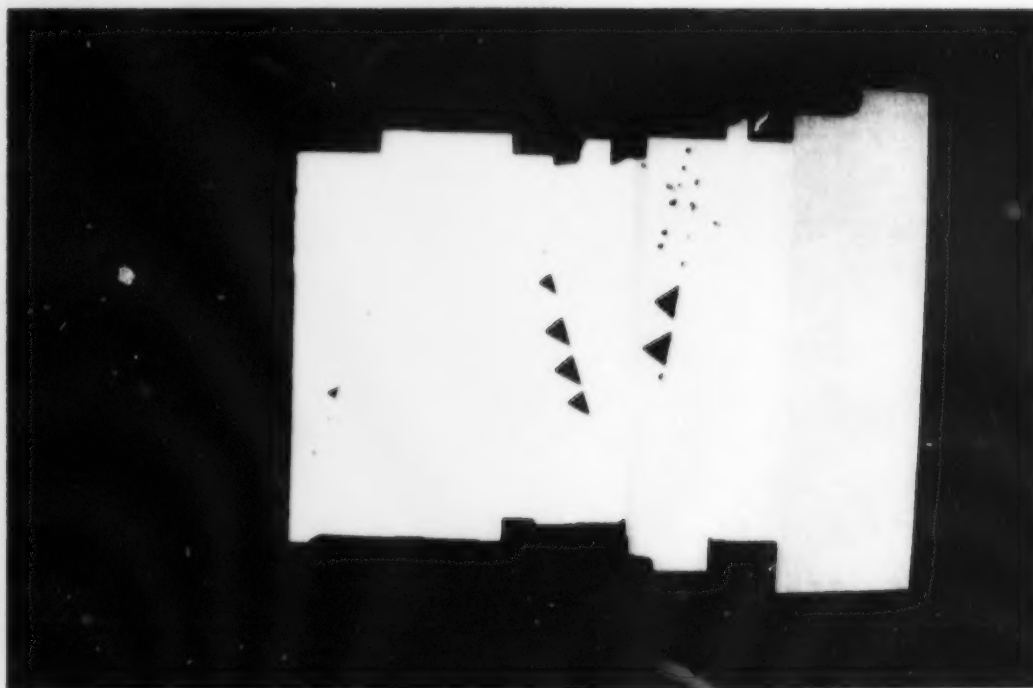


Figure 5-66 3-D South View - Axial Displacements - 4502 Panel

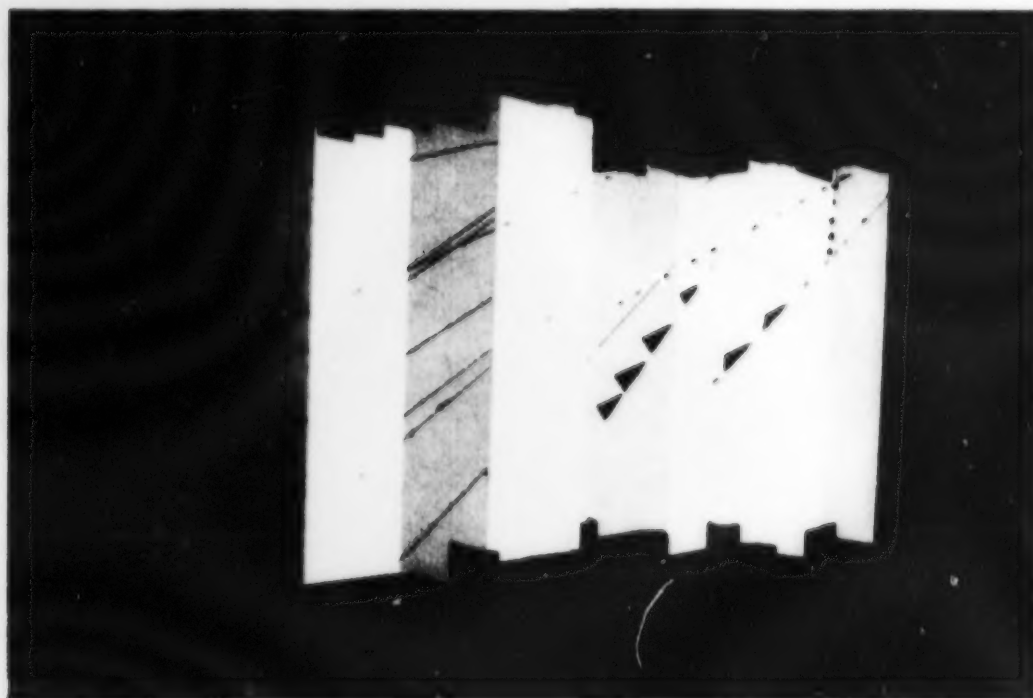


Figure 5-67 3-D South-E View - Axial Displacements - 4502 Panel

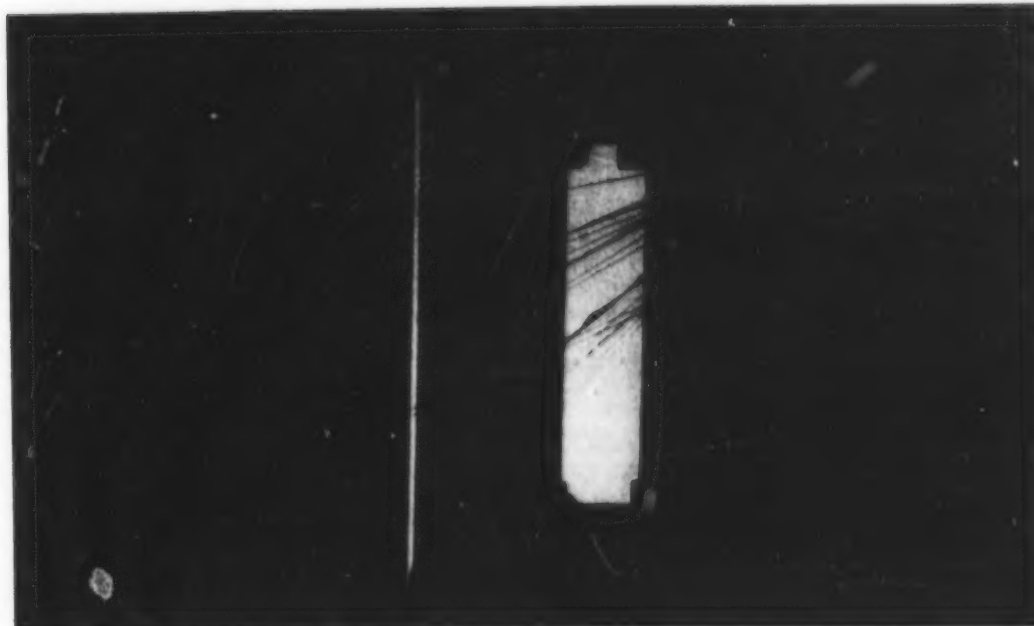


Figure 5-68 3-D East View - Axial Displacements - 4502 Panel

in both holes drilled along this section (75422 and 75424 holes).

The inclinometer probe showed substantial movement during this mining. The displacement was in a negative vertical direction and major movement in the negative horizontal direction in the lower hole drilled on 6385 Section (hole 75424). A negative vertical displacement was also measured in the top Ring 2 monitoring hole (75431 hole). A positive vertical displacement was measured at all depths in the bottom hole in this same ring (hole 75432).

5.10.2. Stress Monitoring

The stress cells installed from 6700 level and the one cell on 6600 level were monitored during the mining of 4502 panel. The strain changes measured at all locations in the monitoring area did not show stress changes of sufficient magnitude to be measured by the monitoring equipment.

5.10.3 Borehole Logging During 4502 Panel Mining

The inspection boreholes on 6600 level were logged with a television camera for the fourth time while panel 4502 was being mined. Unfortunately, time allowed only the holes drilled from 6340 drill station and in the footwall and hangingwall on 6600 level to be logged. The camera monitoring holes (Figure 5-4) drill on 6400 and 6385 Sections (holes 75420, 75421 and 75423), which are located adjacent to 4502 panel, were not at this stage in the project.

A 3-D representation of the visual observations made in the holes is given in Figures 5-69 to 5-74. The only area that showed any substantial increase in highly fractured ground from the previous logging of the holes was near the collar of the holes drilled from 6340 drill station on 6600 level.

There was also an increase in the amount of spalling in this same area which indicated that it was not in the stress relaxation zone up to the end of the previous logging. Another area that showed an increase in spalling in the borehole walls was in the location of the Ring 1 monitoring holes which demonstrates that this area was also out of the relaxation zone at that time. Both these observations agree with the relaxation zone estimated location at those times, shown by the hatched lines in Figure 5-50.

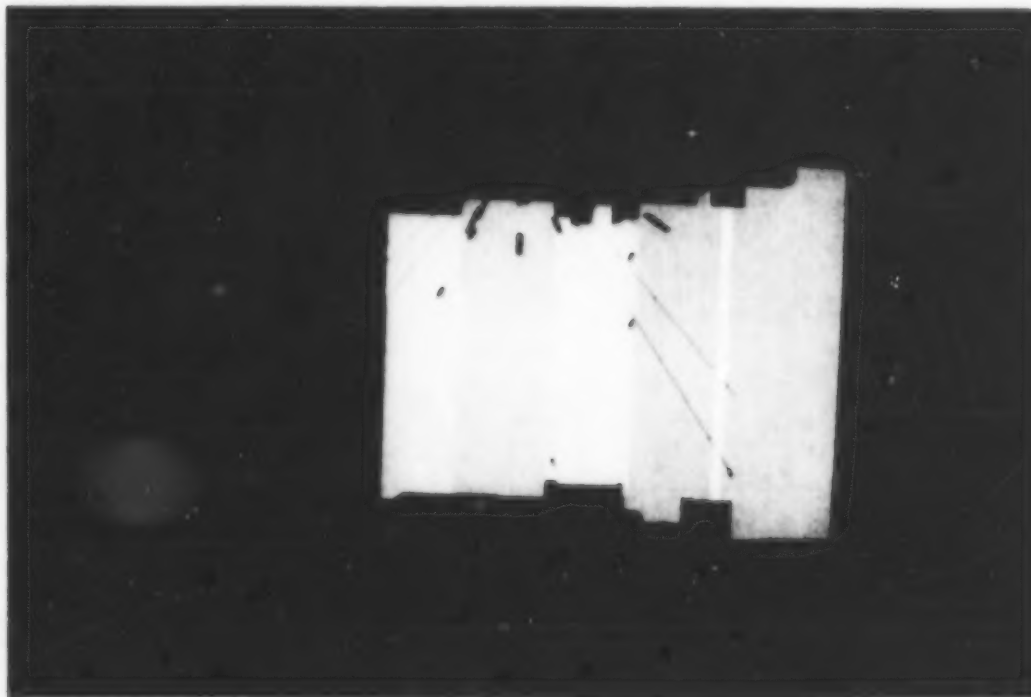


Figure 5-69 3-D South View - Highly Fracture Zones - 4502 Panel

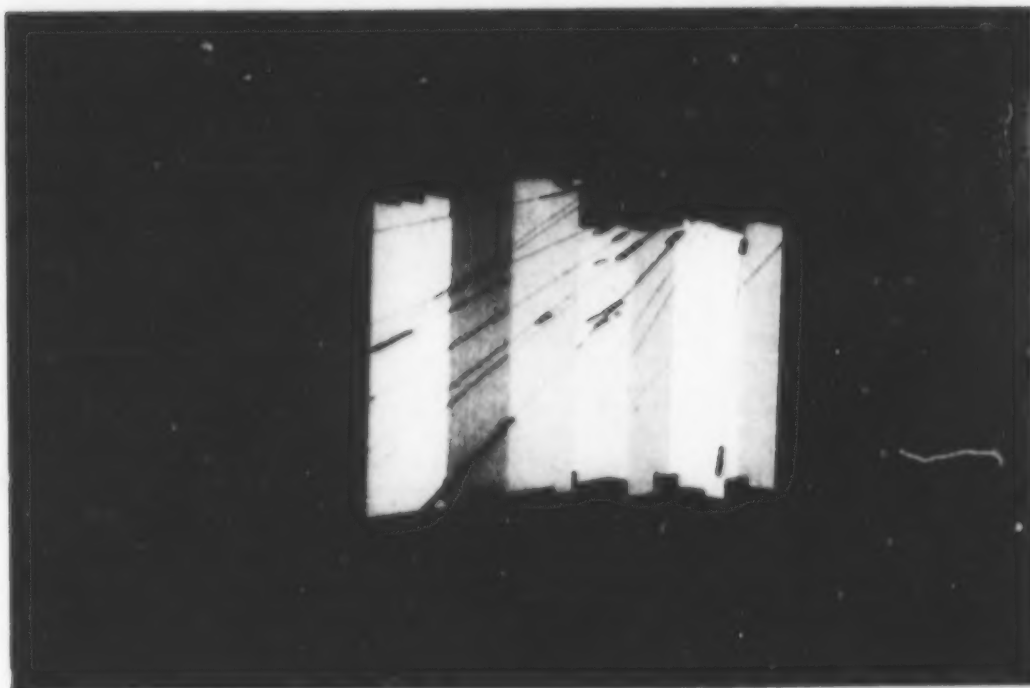


Figure 5-70 3-D S-E View - Highly Fracture Zones - 4502 Panel

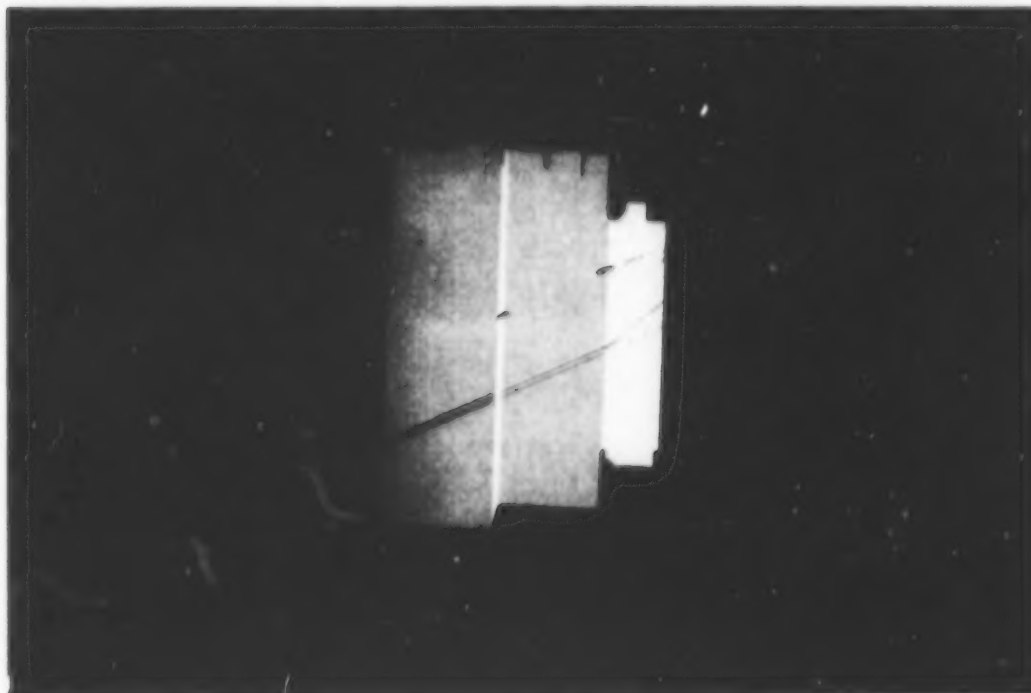


Figure 5-71 3-D East View - Highly Fracture Zones - 4502 Panel

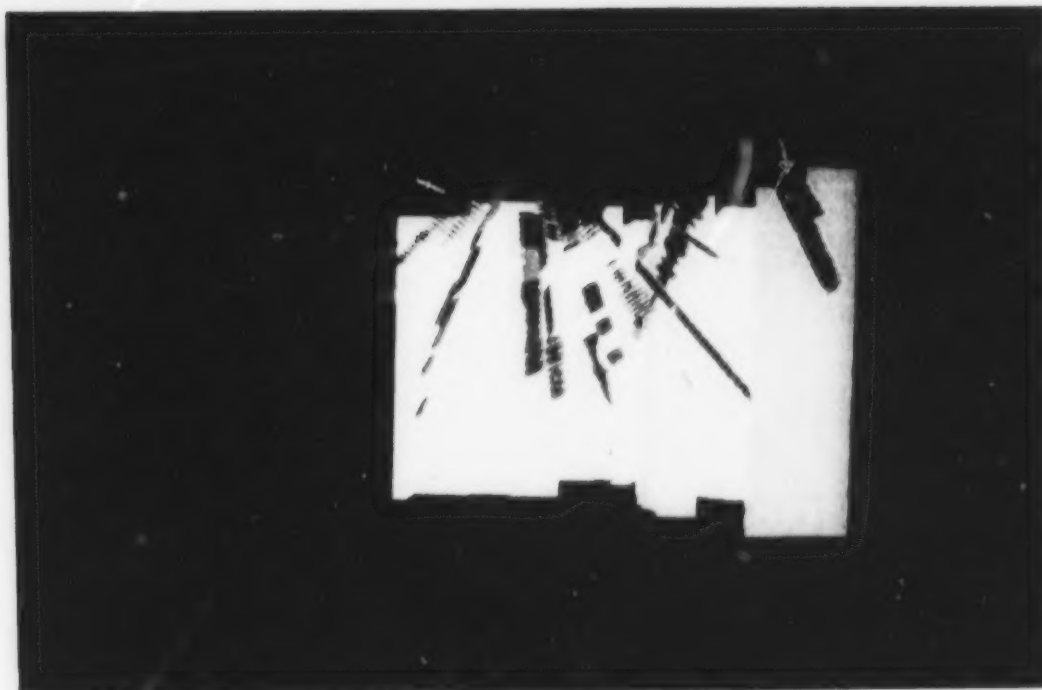


Figure 5-72 3-D South View - Borehole Spalling - 4502 Panel

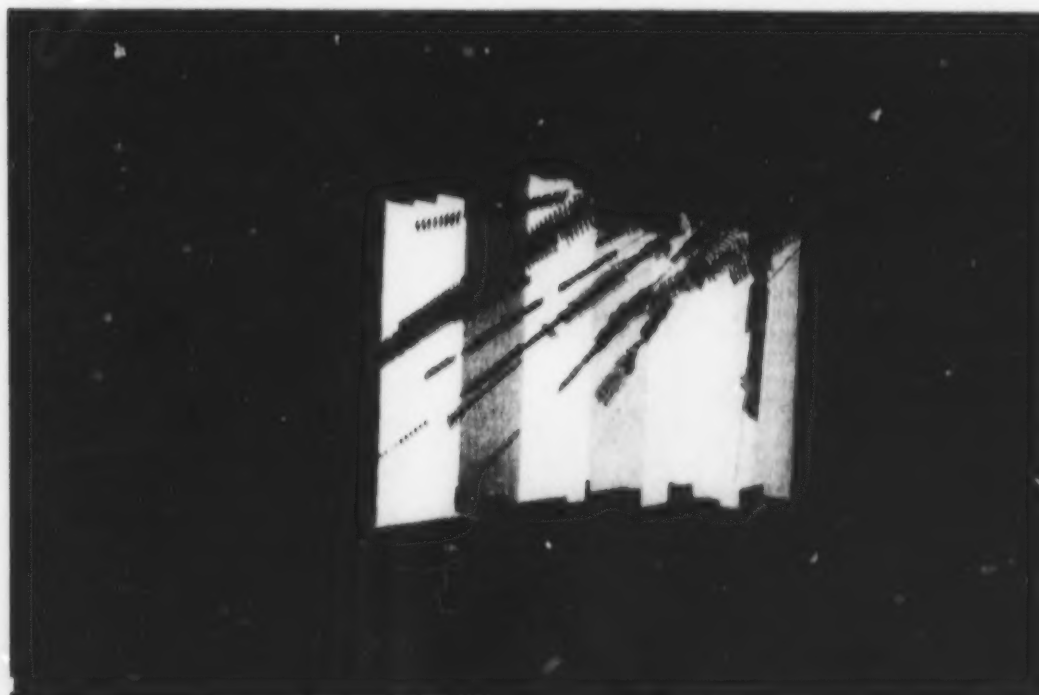


Figure 5-73 3-D S-E View - Borehole Spalling - 4502 Panel

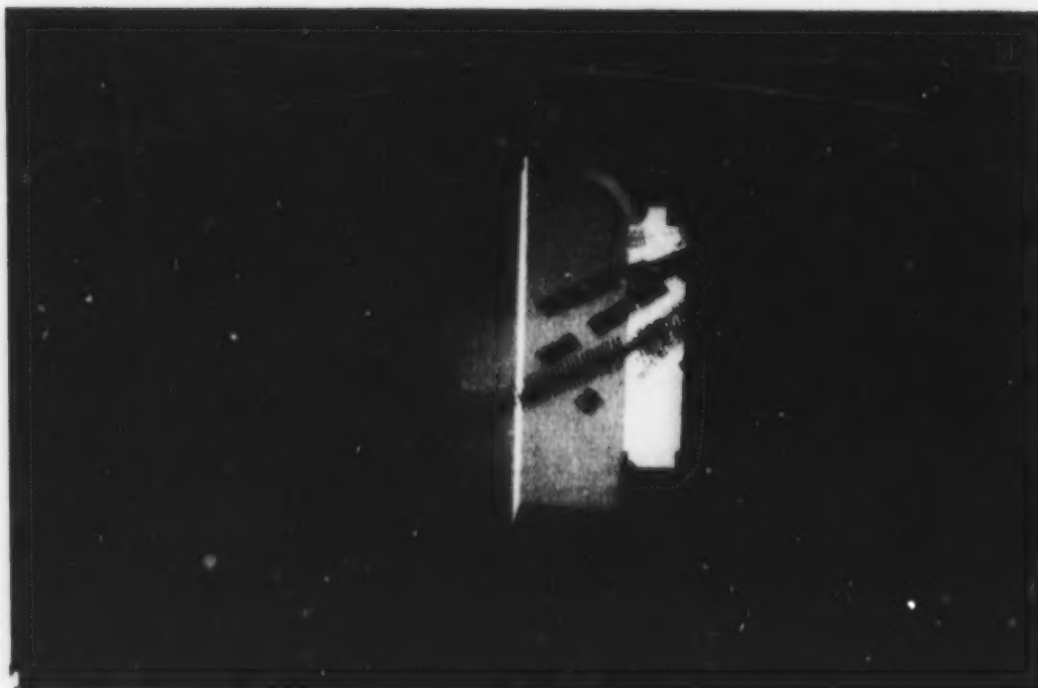


Figure 5-74 3-D East View - Borehole Spalling - 4502 Panel

The boreholes in the hangingwall and the footwall were logged for only the second time in the project. All the holes showed a high degree of spalling in the walls demonstrating that there had been major stress redistributions in this area since they had been initially logged as would be expected at this stage in the mining.

The data from the borehole logging and the displacement and stress change measurements indicate that the mining of 4502 did little to alter the location of the stress relaxation zone because it was within the relaxation zone prior to mining. The conclusions drawn from the logging data agrees with previous estimates of the relaxation zone location and allows, a new estimate of its location to be made as shown by the hatched lines in Figure 5-75.

5.11 4505 V.R.M. Panel Mining (Mining Stage Eight)

The mining of 4505 panel took place between May 7 and Aug. 5/90 which includes a one-month vacation shutdown in July during which no mining was conducted in Creighton Mine. The mining of two panels on the 4300 side of the distress slot overlapped the mining of this panel (Figure 5-76) as did the mining of two panels in the

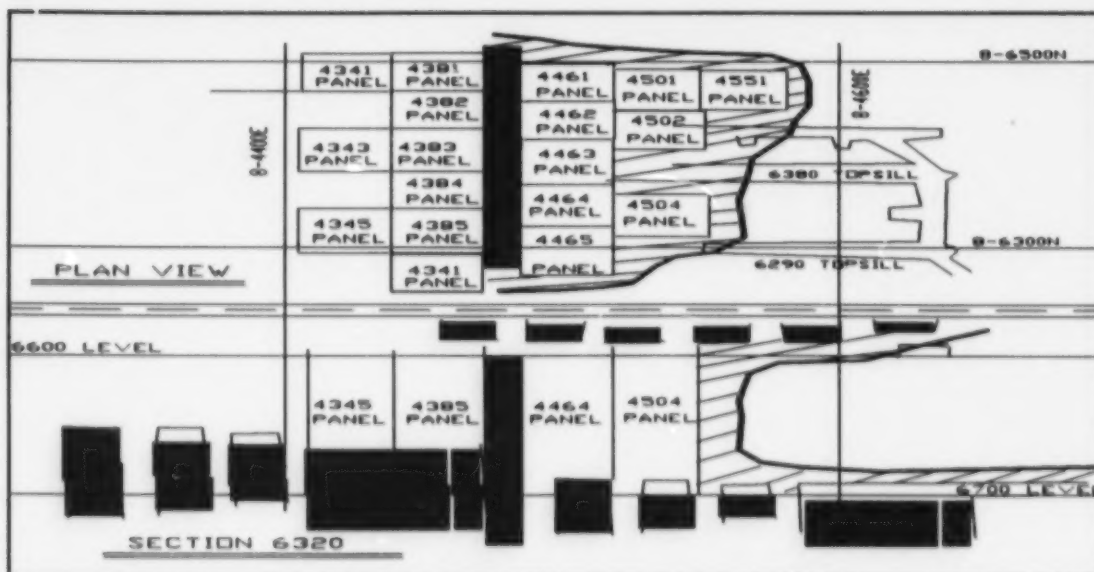


Figure 5-75 Stress Relaxation Zone Location - 4502 Panel Mining

7000 to 6800 level crown (Figure 5-77).

Most of the holes drilled in 4505 panel for blasting showed signs of spalling which indicates that the panel was partially outside the stress relaxation zone. This confirms the estimated location of the relaxation zone shown in Figure 5-76 which was when the drilling took place.

5.11.1 Displacements

The rock mass movement measured during the mining of this panel was relatively high as it has been with the previous panel's mining next to the footwall and hangingwall of the monitoring site. Axial displacements ranging from 0.5 to 2.75 mm were measured throughout the mining block all in directions away from the collars of the boreholes (Figures 5-78 to 5-80).

The inclinometer readings showed an uncharacteristically high degree of movement in both the vertical and horizontal direction to the borehole axis. Relatively large negative displacements were measured in the vertical direction in the bottom hole (Figure 5-4)

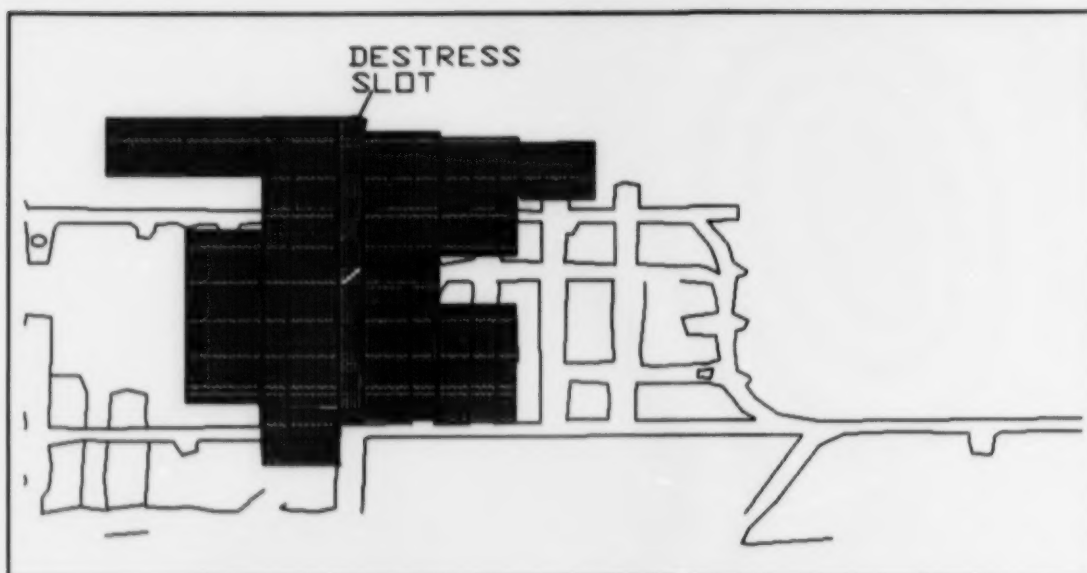


Figure 5-76 6600 Level Plan - 4505 Panel Mining

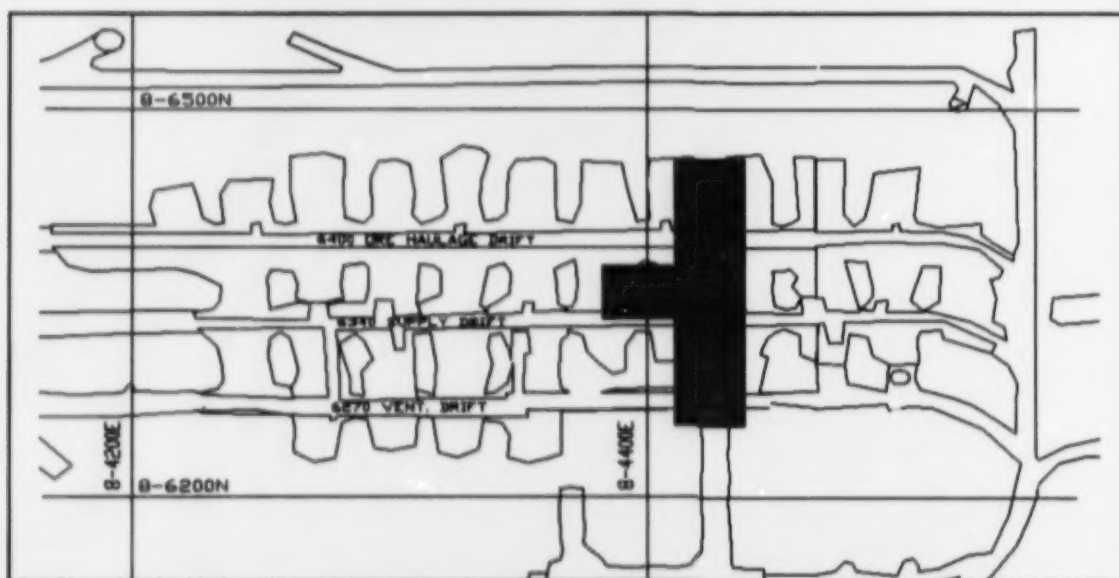


Figure 5-77 6800 Level Plan - Sixth Panel Mining - 7000 Crown

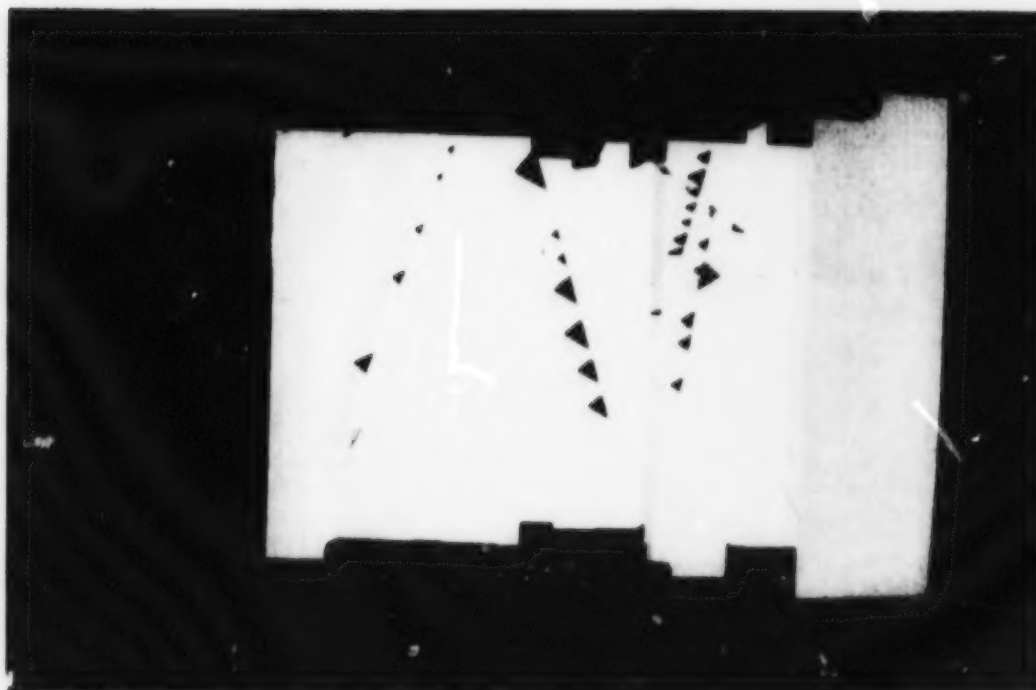


Figure 5-78 3-D South View - Axial Displacements - 4505 Panel

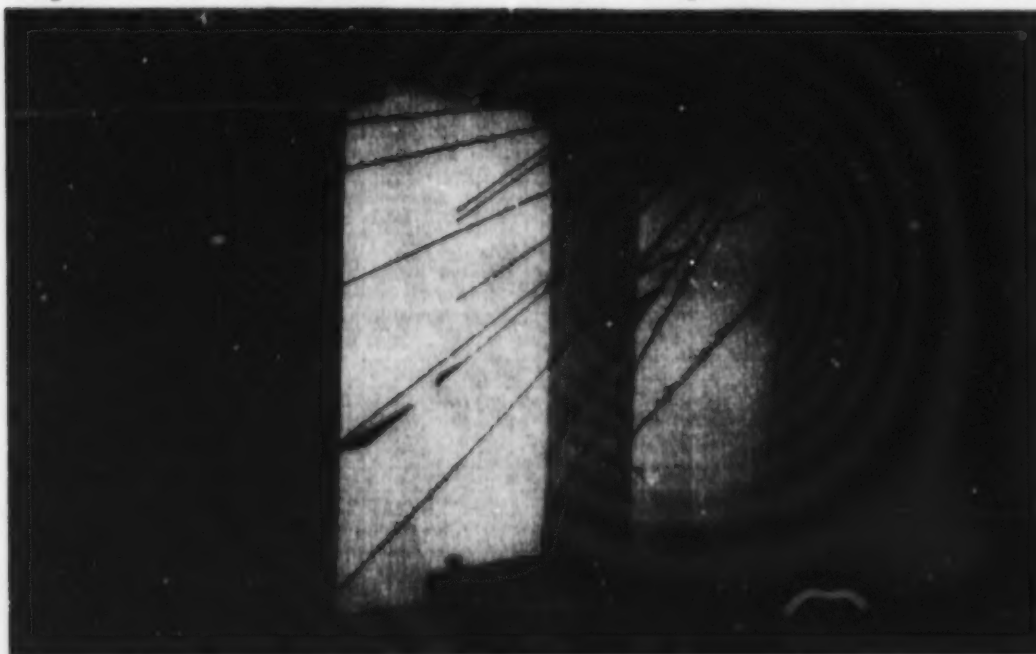


Figure 5-79 3-D South-E View - Axial Displacements - 4505 Panel

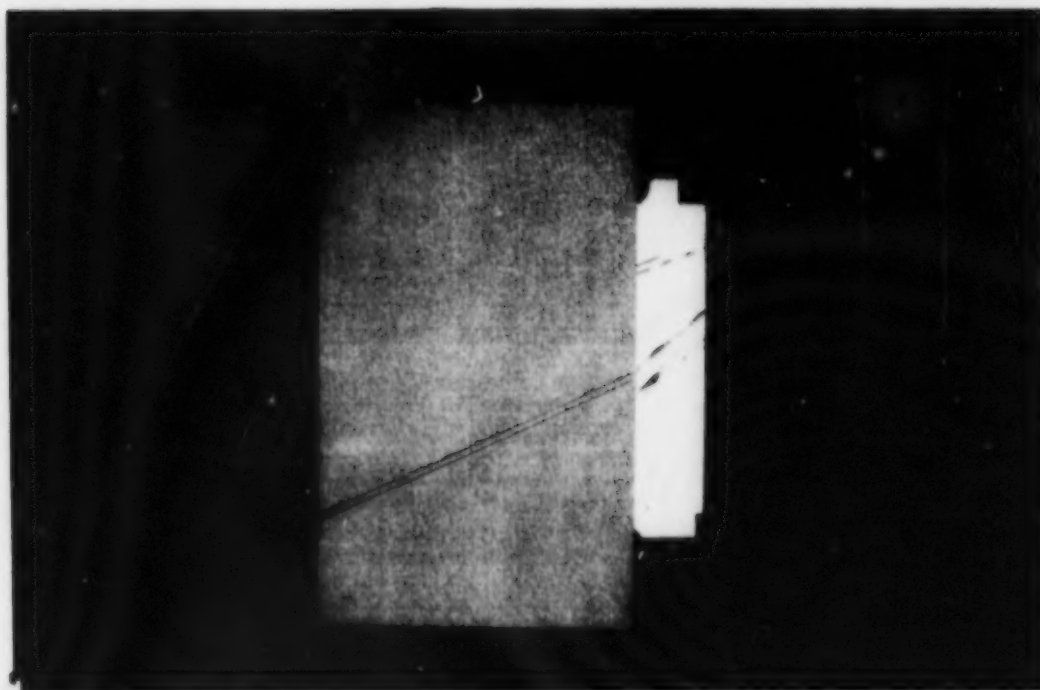


Figure 5-80 3-D East View - Axial Displacements - 4505 Panel

drilled on Section 6385 (hole 75424) as well as positive horizontal displacements. Both negative vertical and horizontal movements were measured in holes in Rings 2 and 4 (holes 75431 75432 and 75438).

5.11.2 Stress Monitoring

The mining of 4505 panel caused substantial stress redistributions monitoring site that was measured by five different points in the 4500 V.R.M. mining block. The location of the stress cell that monitored the change and the magnitude and direction of the total change expressed as principle stresses are shown in Figures 5-81 and 5-82. The plots of the strain change measured by each cell is shown in Figures 5-83 to 5-87.

The strain changes measured by C.S.I.R.O. triaxial cells 3613 and biaxial Yoke cell VG43 (Figures 5-83 and 5-84) both demonstrate that the stress change in the rock mass was triggered after each subsequent blast in the 4505 V.R.M. panel. The saw tooth section of both plots represent the progressive crater blasting of the panel between May 28 and June 28, 1990 each of which caused

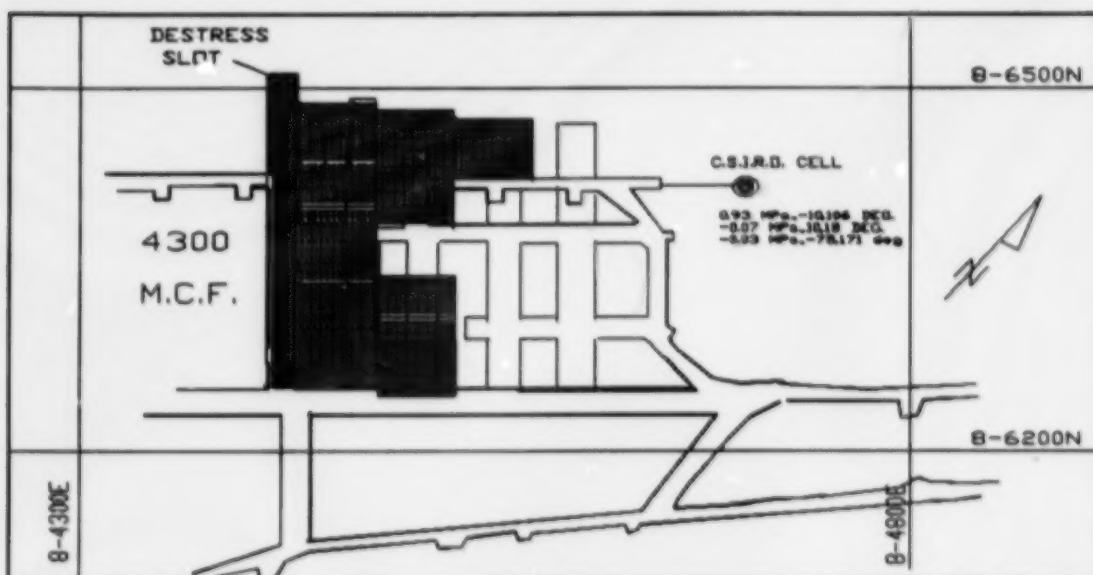


Figure 5-81 6600 Level Plan - Stress Change - 4505 Panel Mining

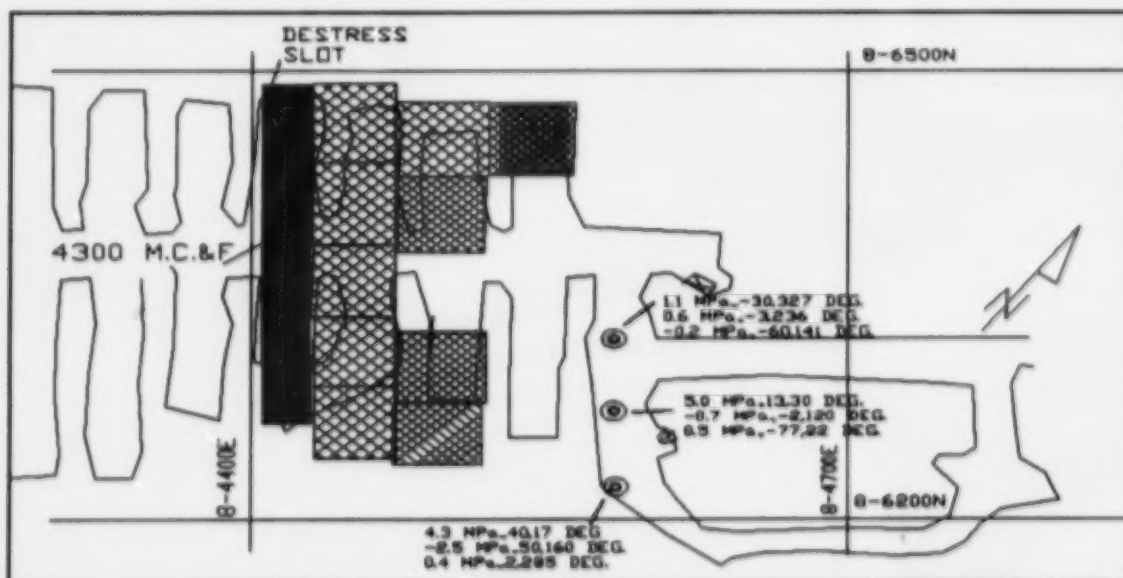


Figure 5-82 6700 Level Plan - Stress Change - 4505 Panel Mining

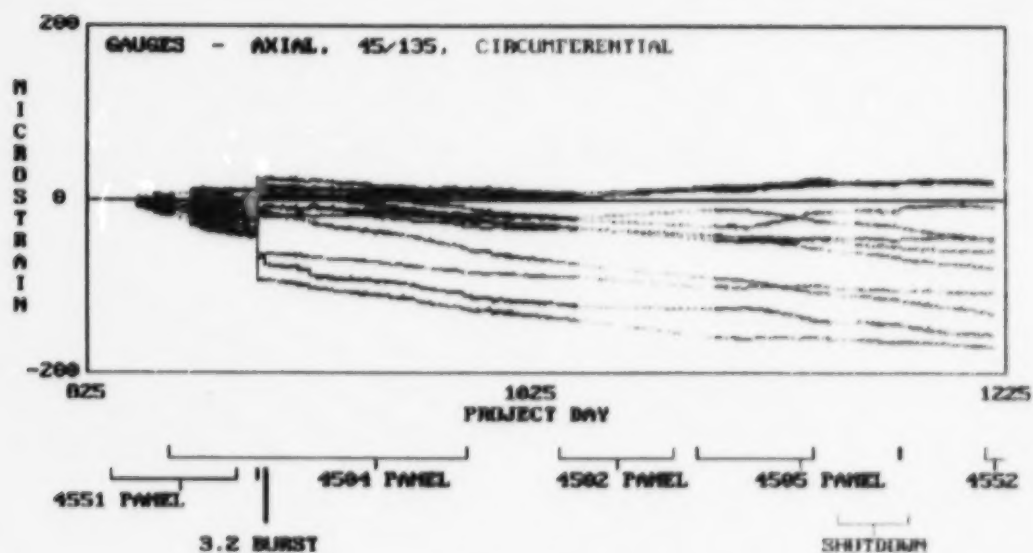


Figure 5-83 Strain Data From Cell 3244 - 4505 Panel Mining

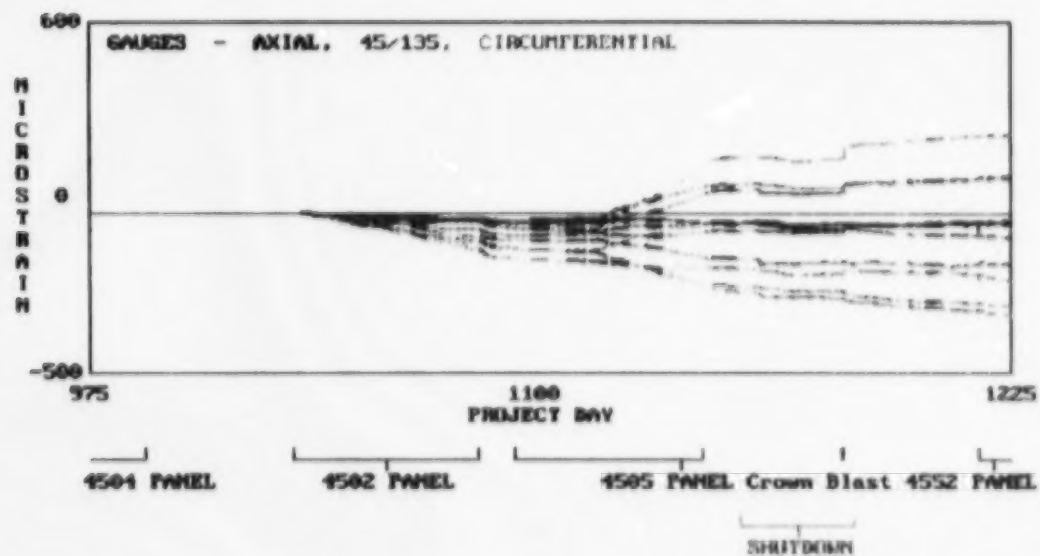


Figure 5-84 Strain Data From Cell YG43 - 4505 Panel Mining

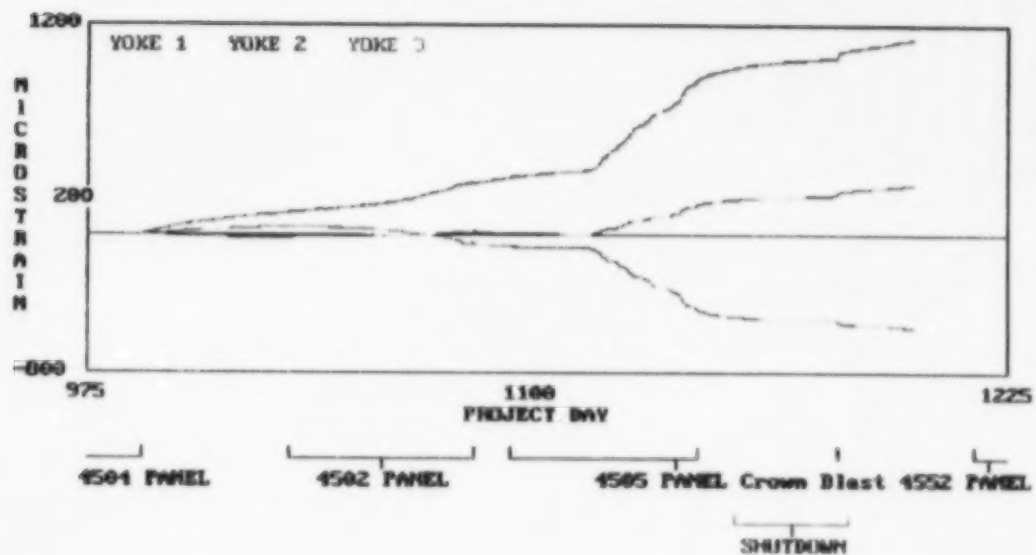


Figure 5-85 Strain Data From Cell 3613 - 4505 Panel Mining

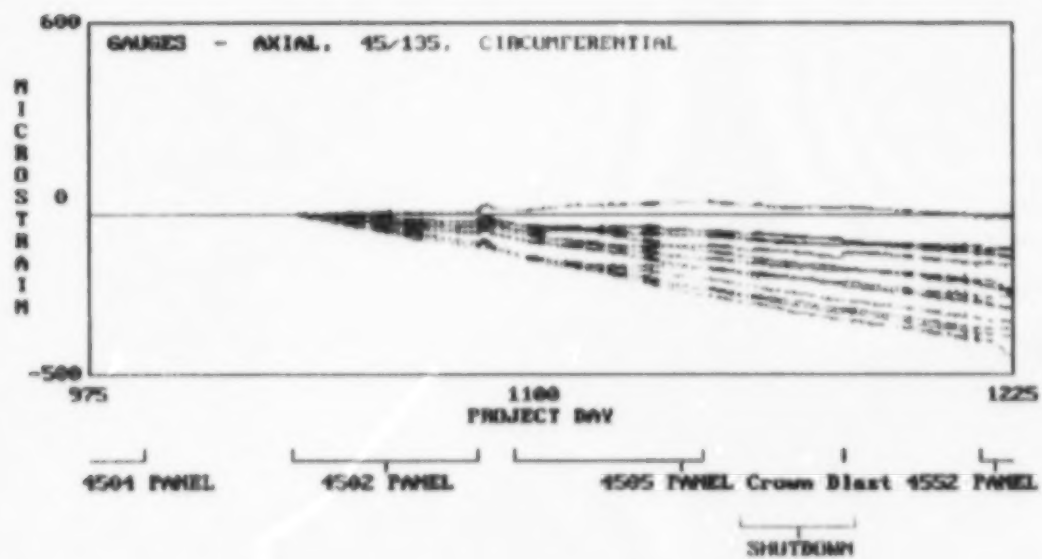


Figure 5-86 Strain Data From Cell 3593 - 4505 Panel Mining

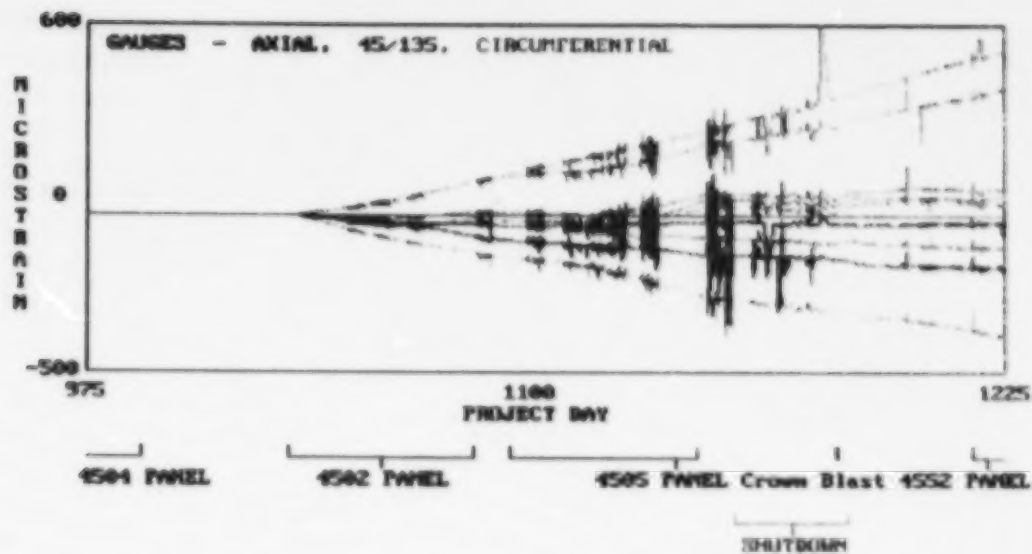


Figure 5-87 Strain Data From Cell 3599 - 4505 Panel Mining

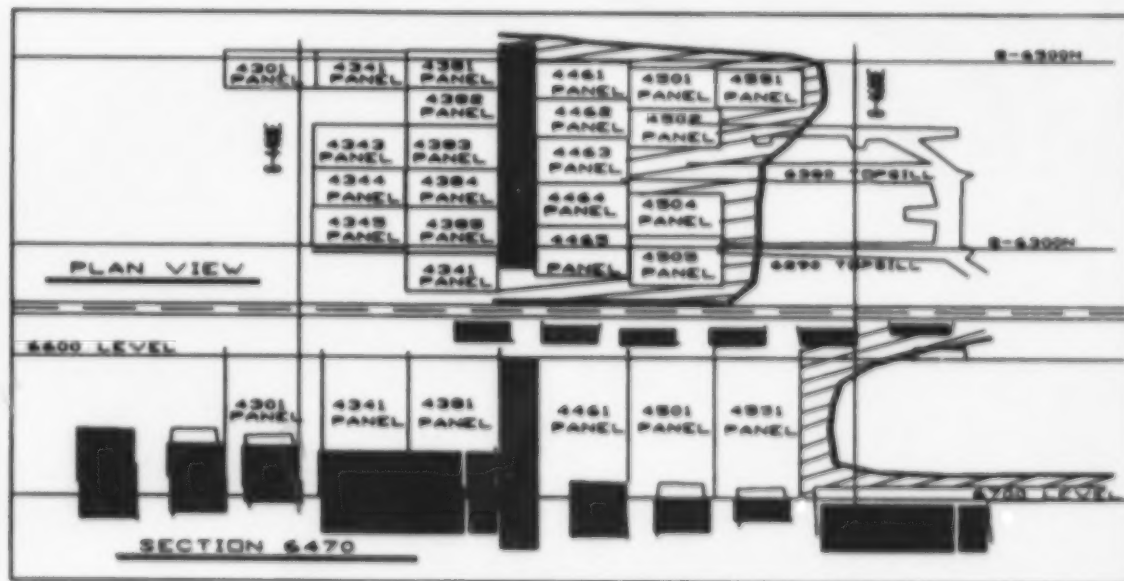


Figure 5-88 Stress Relaxation Zone Location - 4505 Panel Mining

approximately a 0.2 MPa stress change in this hole.

The crown blast in the panel was not taken until the summer vacation shutdown in July was over. The August blast caused the largest single stress change during the mining of this panel with a magnitude of -0.9 MPa measured in cell 3613. The accumulative stress change over the May 28th to June 28th mining period amounted to a -4.1 MPa.

The displacement and stress change data indicates that the mining of 4505 panel caused some major redistribution of the stresses in the footwall section of the monitoring site. This redistribution caused a change in the location of the stress relaxation zone as shown by the hatched lines in Figure 5-88.

6.0 DISCUSSION AND CONCLUSIONS

Because of the contractual agreement that governed the time limits on the work conducted in this field monitoring project, it was concluded after the mining of 4505 panel. The data collected, while less than complete is considered to be sufficient to describe the rock mass response to the mining in the monitoring site over the four and one-half year duration of the project.

Conducting a field monitoring project of this magnitude in an active mining environment is difficult. One of the lessons learned about the installation of monitoring instrumentation is not to try and install monitoring equipment in an active development area. The repeated attempts to maintain the cables in these active areas proved to be a very futile exercise.

It is recommended that monitoring equipment be installed only in areas of the mine where the development mining has been completed and ideally away from the common route travelled by mobile equipment. Most of the instrumentation lost in this project was through the repeated damaging of the cables resulting from blasting or from mobile equipment movement. Seldom was the instrumentation itself damaged unless it was intersected by the progressive mining in the monitoring site.

Some of the instrumentation used in this project was more suited for underground monitoring than others. The axial displacement monitoring with the solid rod extensometers was quite successful. The planer displacement monitoring with the inclinometer proved to be less successful. The grouting of the inclinometer casings resulted in cement paste contaminating the casing interior. This produced a uneven interior surface on which to run the inclinometer probe. This resulted in the data collected with the inclinometer containing sufficient noise to make it extremely difficult to interpret.

There were also difficulties with the cables that ran from the instrumentation to the datalogger corroding over time and eventually having to be replaced. The extreme humidity and acidic nature of the sulphide ore environment reduces the life of any exposed end of a cable from 6 to 12 months. In wet areas of the mine this is reduced to 3 months. All cable ends must be covered with an epoxy or heat shrink material to prevent exposure to the mine air.

The initial approach to determining the stress changes associated with the mining in this project was to overcore CSIRO triaxial stress cells installed in strategic locations around the monitoring site at different stages of the mining. This approach did not work because of the difficulties encountered in finding suitable ground conditions close to the mining in which to install and overcore the cells. There were also the normal problems of a less than 100%

success rate in the overcoring process which slowed the data collection even further.

This method of determining stress changes was abandoned mid-way through the project and replaced with a stress monitoring program using CSIRO triaxial cells and biaxial Yoke cells. The performance of these cells proved to be more than satisfactory with stress changes as low as 0.2 MPa being recorded. This method of monitoring stress changes in any hardrock mining environment is highly recommended.

Of all the data collected in the project the visual observations made from logging of diamond drill core, the logging of boreholes with a television camera and general observations made in the access drifts to the monitoring site proved to be the most useful. The physical changes visually seen in the rock mass made the interpretation of the data collected by the instrumentation possible. The combination of the two resulted in an interpretation of the rock mass response to the progressive mining that is considered to be accurate and reliable.

7.0 REFERENCES

Herget, G., Technical Notes: Stress Assumptions for Underground Excavations in the Canadian Shield. Int. J. Rock Mech. Min. Sci. & Geomech. Vol. 24 No. 1 95-97, 1987.

Herget, G., Pahl, A., & Oliver, P., Ground Stress Below 3000 Feet. Internal Report, Elliot Lake Laboratory, CANMET, Dept. Energy Mines and Resources, Canada, 1975.

Herget, G. & Miles, P., Stress Determination at Creighton Mine, Sudbury, Ontario; Internal Report, Elliot Lake Laboratory, CANMET, Dept. Energy Mines and Resources, Canada, 1977.

Landriault, D.A.K., 1988, The Bulk Mining at Depth Field Monitoring Project: Ground Displacement, Presented at the 15th Canadian Rock Mechanics Symposium in Toronto, Ontario, Canada.

APPENDIX A

LIST OF DATA FILES

<u>Data File Name</u>	<u>Data File Description</u>
FEIDSTRS.WK1	Field stresses at this depth in lower Creighton Mine.
ROCKSTRE.WK1	Intact properties for the rock materials that make up the monitoring sites.
INISCANL.WK1	The scanline data collected for 6600 and 6700 levels, 4500 block prior to the commencement of monitoring in this project.
P462CM66.WK1	Drift closure data from the closure meter locations on 6600 level, 4500 block during the mining of 4462 panel.
P462FJP1.WK1	The data collected during the mining of panel 4462, 4500 block from the flat-jack cells buried in 4461 panel.
P464DE27.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75427, drilled from 6600 level in 4500 block during the mining of 4464 panel.
P464DE31.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75431, drilled from 6600 level in 4500 block during the mining of 4464 panel.
P464DE38.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75438, drilled from 6600 level in 4500 block during the mining of 4464 panel.
P464DE41.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75441, drilled from 6600 level in 4500 block during the mining of 4464 panel.
P501DE27.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75427, drilled from 6600 level in 4500 block during the mining of 4501 panel.
P501DE31.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75431, drilled from 6600 level in 4500 block during the mining of 4501 panel.

P501DE38.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75438, drilled from 6600 level in 4500 block during the mining of 4501 panel.
P501DE41.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75441, drilled from 6600 level in 4500 block during the mining of 4501 panel.
P501FJP4.WK1	The data collected during the mining of panel 4501, 4500 block from the flat-jack cells buried in 4464 panel.
P501SMHW.WK1	Stress monitoring data from hangingwall monitoring site 2 on 6600, 4500 block during the mining of 4501 panel.
P465DE27.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75427, drilled from 6600 level in 4500 block during the mining of half 4463 and all 4465 panel.
P465DE31.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75431, drilled from 6600 level in 4500 block during the mining of half 4463 and all 4465 panel.
P465DE38.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75438, drilled from 6600 level in 4500 block during the mining of half 4463 and all 4465 panel.
P465DE41.WK1	Ground displacement data from the datalogger monitored solid rod extensometers located in hole 75441, drilled from 6600 level in 4500 block during the mining of half 4463 and all 4465 panel.
P465FJP4.WK1	The data collected during the mining of half 4463 and all panel 4465, 4500 block from the flat-jack cells buried in 4464 panel.
P465FJPA.WK1	The data collected during the mining of half 4463 and all panel 4465, 4500 block from the flat-jack cells buried 12 meters below 6600 level in 4501 panel.
P465FJPB.WK1	The data collected during the mining of half 4463 and all panel 4465, 4500 block from the

flat-jack cells buried 25 meters below 6600 level in 4501 panel.

P465SMFW.WK1	Stress monitoring data from footwall monitoring site 1 on 6600, 4500 block during the mining of half of 4463 and all 4465 panel.
P465SE67.WK1	Ground displacement data from the single point extensometers located in the back on 6700 level, 4500 block during the mining of half 4463 and all 4465 panel.
BLASTING.WK1	The dates and time of all blasting in each of the V.R.M. panels mined over the three years of monitoring in 4500 block.
MICROSEI.WK1	The dates and time of all microseismic events during the mining of each of the V.R.M. panels mined over the three years of monitoring in 4500 block.
BHLCOMB.WK1	The borehole camera logging data collected for the monitoring holes drilled from 6600 level into 4500 block. This file is a comparison of borehole camera logging data collected after the mining of 4461, 4462, 4465, 4502 and 4552 panels.
TE66COMB.WK1	Drift closure data from the tape extensometer stations on 6600 level, 4500 block during the mining of all panels.
ME02COMB.WK1	Ground displacement data from the manually monitored solid rod extensometers located in hole 75402, drilled from 6600 level in 4500 block during the mining of 4461 and 4462 panels.
ME03COMB.WK1	Ground displacement data from the manually monitored solid rod extensometers located in hole 75403, drilled from 6600 level in 4500 block during the mining of 4461 and 4462 panels.
ME46COMB.WK1	Ground displacement data from the manually monitored solid rod extensometers located in hole 75446, drilled from 6600 level in 4500 block during the mining of 4461 and 4462 panels.
MEIN19CB.WK1	Ground displacement data from the manually monitored solid rod extensometers and data from the inclinometer located in hole 75419,

drilled from 6600 level in 4500 block during the mining of 4461 and 4462 panels.

MEIN22CB.WK1

Ground displacement data from the manually monitored solid rod extensometers and data from the inclinometer located in hole 75422, drilled from 6600 level in 4500 block during the mining of all panels.

MEIN24CB.WK1

Ground displacement data from the manually monitored solid rod extensometers and data from the inclinometer located in hole 75424, drilled from 6600 level in 4500 block during the mining of all panels.

MEIN27CB.WK1

Ground displacement data from the manually monitored solid rod extensometers and data from the inclinometer located in hole 75427, drilled from 6600 level in 4500 block during the mining of all panels.

MEIN31CB.WK1

Ground displacement data from the manually monitored solid rod extensometers and data from the inclinometer located in hole 75431, drilled from 6600 level in 4500 block during the mining of all panels.

MEIN32CB.WK1

Ground displacement data from the manually monitored solid rod extensometers and data from the inclinometer located in hole 75432, drilled from 6600 level in 4500 block during the mining of all panels.

MEIN38CB.WK1

Ground displacement data from the manually monitored solid rod extensometers and data from the inclinometer located in hole 75438, drilled from 6600 level in 4500 block during the mining of all panels.

ME41COMB.WK1

Ground displacement data from the manually monitored solid rod extensometers located in hole 75441, drilled from 6600 level in 4500 block during the mining of all panels.

BHC75277.WK1

Diamond drill core logging data collected from hole 75277 drilled from 6600 level 6420 H.W. drift at an aximuth of 230° and a dip of -26° - 30°.

BHC75278.WK1

Diamond drill core logging data collected from hole 75278 drilled from 6600 level 6420 H.W. drift at an aximuth of 230° and a dip of -45°.

BHC75402.WK1	Diamond drill core logging data collected from hole 75402 drilled from 6600 level 6420 GWY at section 4469. Aximuth of 351° and a dip of -21°.
BHC75407.WK1	Diamond drill core logging data collected from hole 75407 drilled from 6600 level 6250 GWY at section 4469. Aximuth of 180° and a dip of 0°.
BHC75408.WK1	Diamond drill core logging data collected from hole 75408 drilled from 6600 level 6250 GWY at section 4469. Aximuth of 180° and a dip of 0°.
BHC75405.WK1	Diamond drill core logging data collected from hole 75405 drilled from 6600 level 6250 GWY at section 4469. Aximuth of 360° and a dip of -42°.
BHC75410.WK1	Diamond drill core logging data collected from hole 75410 drilled from 6600 level 6250 GWY at section 4525. Aximuth of 180° and a dip of 0°.
BHC75411.WK1	Diamond drill core logging data collected from hole 75411 drilled from 6600 level 6250 GWY at section 4550. Aximuth of 180° and a dip of 0°.
BHC75413.WK1	Diamond drill core logging data collected from hole 75413 drilled from 6600 level 6420 H.W. drift at section 4600. Aximuth of 360° and a dip of 0°.
1LE23244.WK3	Continuously monitored C.S.I.R.O. cell #3244 installed in 6600 level 6420 H.W. drift. Day 248/89 to Day 310/89.
2LE23244.WK3	Continuously monitored C.S.I.R.O. cell #3244 installed in 6600 level 6420 H.W. drift. Day 311/89 to Day 024/90.
3LE23244.WK3	Continuously monitored C.S.I.R.O. cell #3244 installed in 6600 level 6420 H.W. drift. Day 025/90 to Day 256/90.
1LE13591.WK3	Continuously monitored C.S.I.R.O. cell #3591 installed in hole #75464 drilled from 6700 level. Day 262/89 to Day 319/89.
1LE23594.WK3	Continuously monitored C.S.I.R.O. cell #3594 installed in hole #75461 drilled from 6700 level. Day 319/89 to Day 068/90.
1LE53590.WK3	Continuously monitored C.S.I.R.O. cell #3590 installed in hole #75459 drilled from 6700 level. Day 068/90 to Day 305/90.

1LE53593.WK3	Continuously monitored C.S.I.R.O. cell #3593 installed in hole #75466 drilled from 6700 level. Day 118/90 to Day 284/90.
1LE53599.WK3	Continuously monitored C.S.I.R.O. cell #3599 installed in hole #75467 drilled from 6700 level. Day 068/90 to Day 305/90.
1LE53613.WK3	Continuously monitored C.S.I.R.O. cell #3613 installed in hole #75460 drilled from 6700 level. Day 068/90 to Day 305/90.
LE53594A.WK3	Continuously monitored C.S.I.R.O. cell #3594 installed in hole #75461 drilled from 6700 level. Day 068/90 to Day 166/90.
1JGYG043.WK3	Continuously monitored Yoke cell #YGO43 installed in hole #75460 drilled from 6700 level. January 26/90 to August 24/90.
2JGYG043.WK3	Continuously monitored Yoke cell #YGO43 installed in hole #75460 drilled from 6700 level. May 15/90 to Nov. 1/90.
1JGYG044.WK3	Continuously monitored Yoke cell #YGO44 installed in hole #75472 drilled from 6700 level. January 26/90 to August 24/90.
2JGYG044.WK3	Continuously monitored Yoke cell #YGO44 installed in hole #75472 drilled from 6700 level. May 15/90 to November 26/90.
1LE53594.WK3	Continuously monitored C.S.I.R.O. cell #3594 installed in hole #75461 drilled from 6700 level. Day 068/90 to Day 313/90.